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# STUDY ON INTRODUCTION OF THE EXCLUSIVE OVER/UNDERPASS FOR SMALL VEHICLES IN JAPAN

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**Abstract:** This study aims at investigating the effectiveness of exclusive over/underpasses for small vehicles in alleviating traffic congestion at a saturated intersection in Japan. The design standard of the road for only small vehicles has been established in the road structure ordinance that was revised in 2003. Its effectiveness compared with ordinary over/underpasses is still ambiguous. Therefore, the micro traffic simulation was used to clearly evaluate the impacts of this facility at a single intersection. The evaluation was performed based on changing the reduction of travel time passing through the intersection. It was found that the exclusive over/underpass for small vehicles can alleviate congestion effective ordinary over/underpass, but its construction cost is lower about 30% than the ordinary over/underpass. Furthermore, the heavy vehicles ratio significantly affects its performance. This study suggested that an intersection suitable for an exclusive over/underpass should be selected carefully with respect to heavy vehicle ration in the traffic.

**Key Words:** Traffic Simulation, Small Vehicles, Exclusive Over/underpass

## 1. INTRODUCTION

In general, capacity of entire road network is dominated by capacity at intersections. Thus, there is a possibility to enhance the performance of the whole network in urban area, if capacity of serious bottleneck of an intersection can be increased. Therefore, An implementation of an over/underpass for an intersection has been one of the most desirable measures to alleviate traffic congestion. However, because of the requirements of huge construction costs and wide spaces, this measure becomes impractical. To overcome these obstacles, the exclusive over/underpass for small vehicles is proposed with less construction cost and minimum environmental degradation. Although, the resource consumptions of this new facility are not as much of the ordinary over/underpass, but there is still a question on its effectiveness in improving congestion condition. This point should be evaluated in this study. Because most existing evaluation approaches to evaluate a capacity of an intersection seems inapplicable for the situation under oversaturated flow and wide range of heavy vehicle mixing rate, the study also needs to develop a specific evaluation methodology for this particular facility. Eventually, it intends to investigate the feasibility to implement the exclusive over/underpass for small vehicles as a countermeasure for alleviating traffic congestion at a saturated intersection by using micro simulation model.

First, the basic concept of exclusive over/underpasses for small vehicles is provided, and then the proposed methodology to evaluate its effectiveness is explained. To clearly perceive the evaluations, two intersections in Chiba Prefecture are evaluated as case studies. Finally, the findings are drawn into the conclusion part.

## 2. THE EXCLUSIVE OVER/UNDERPASS FOR SMALL VEHICLES

As explained before, it is obvious that an intersection has a possibility to reduce the capacity of whole road network, so an overpass or underpass is one of effective improvements. However, to implement such facilities it is necessary to have enough spaces, including road width and road length, for the construction. Under this condition, it requires not only additional land, but also huge budgets. This is the reason why an over/underpass has been applied seldom in Japan until now.

In July 2003, the **Road Structure Ordinance of Japan** was revised based on the concept of **Road Performance Design**. In the ordinance, the term of "small road" is defined as "Exclusive Road for Small Vehicles". The small vehicle means the vehicle that its size within length 6m, width 2m, and height 2.8m. To implement an exclusive over/underpass for small vehicles, it is much easier than implementing an over/underpass for all vehicles, such as requirements of road width and vertical spaces, etc. This is obvious when one considers the difference between Figure 1 and 2. While Figure 1 demonstrates a design of an exclusive underpass for small vehicles, Figure 2 shows a design of an underpass for all vehicles. The dimensions of an exclusive underpass can be reduced from an ordinary underpass. For example, the lane width can be reduced from 3.25 to 2.75 m, and from 250 to 210 m for the road length of underpass section. Another advantage of an exclusive overpass is that it can significantly decrease the weight of structure from 254 to 30 Kilo Newton (kN).

These physical improvements benefit for minimizing construction costs, providing spaces for two-level crossing intersection, and modifying the structure under the physical restrictions. As shown in the reports of Ministry of Land, Infrastructure and Transport and the studies conducted by authors, it is found that the construction costs can be reduced about 30%. Table 1 illustrates the comparison of estimated construction costs of exclusive over/underpasses for small vehicles and all vehicles from two intersections. It is obvious that the costs could be decreased from 8.089 to 5.272 Million Yens or 29.2 % for both intersections.

Normally, under a plan to implement an exclusive over/underpass for small vehicles, someone may be worried about the management of safety. It is recommended that other types of vehicles, excluding small and emergency vehicles, should be prohibited to run on this facility. From many studies of Ministry of Land, Infrastructure and Transport, they have proposed a solution to establish Vehicle Control Station for everyplace. This is possible when consider the safety of structure based on a design of concrete standard. Whenever a vehicle that its height exceeds the limitation is approaching to an exclusive underpass for small vehicles, at the entrance of grade separation facility a caution will be given to the vehicle to avoid landing on the underpass.

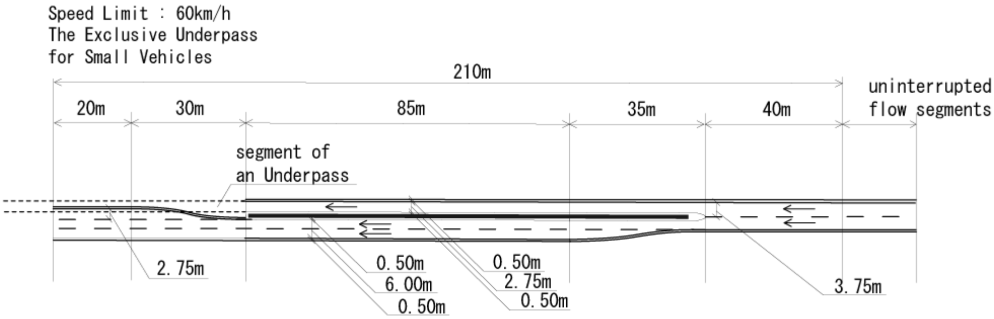



Figure 1. Introduction of an Exclusive Underpass for small vehicles

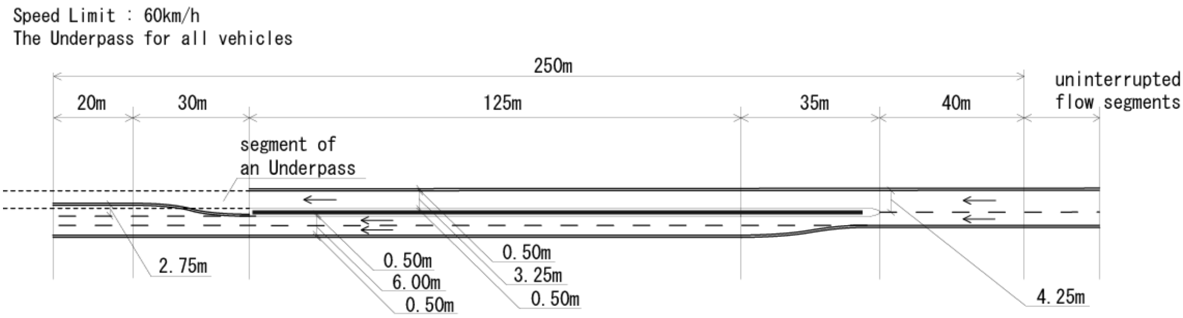



Figure 2. Introduction of an Underpass for all vehicles

Table 1. The cost comparisons of underpass for small and all vehicles from 2 intersections.

○Intersection A

| | The overpass for all vehicles [milion YEN] | The Exclusive Overpass for small vehicles [milion YEN] | The rate of cost reduction [%] |
|---|---|---|---|
| Land | 19.950 | 13.854 | 30.6 |
| Construction | 8.089 | 5.727 | 29.2 |
| Total | 28.039 | 19.581 | 30.2 |

○Intersection B

| | The overpass for all vehicles [milion YEN] | The Exclusive Overpass for small vehicles [milion YEN] | The rate of cost reduction [%] |
|---|---|---|---|
| Land | 18.240 | 12.667 | 30.6 |
| Construction | 8.089 | 5.727 | 29.2 |
| Total | 26.329 | 18.394 | 30.1 |

The utilization of exclusive over/underpasses for small vehicles, though can provide a lot of advantages, it is still questionable that it is really effective in mitigating traffic congestion or not. In the next section, the study aims at investigating the effectiveness of this kind of facility.

## 3. THE EFFECTIVENESS EVALUATION OF EXCLUSIVE OVER/UNDERPASS

Basically, to consider the effectiveness of a two-level crossing, it can consider into two points. The first concerns about the impact on total travel time for all vehicles passing through the intersection that established a general over/underpass for small vehicles. The second focuses on evaluating traffic conditions of an at-grade intersection before and after the implementation. However, these traditional methods are unsuitable for evaluating an exclusive over/underpass for small vehicles. This study has developed an appraisal alternative based on the evaluation methods of intersection. The paper illustrates that how the proposed approach is appropriate in investigating the effectiveness of exclusive over/underpasses.

At the beginning, the basic concept of traditional intersection evaluation is described. The important factors or parameters are necessarily mentioned also. Definitely, such traditional methods can be directly applied for exclusive over/underpasses for small vehicles, therefore some additional modification or validation techniques must be employed through the application of micro traffic simulations.

### 3.1 Basic of Intersection Evaluation

The evaluation method of a signalized intersection generally is relied on two factors, consisting of intersection performances and traffic conditions. The saturation flow rate and intersection flow ratio are the parameters for considering performances of intersection, while the traffic conditions consider about the parameters of delay and maximum queue length. The Ministry of Land, Infrastructure and Transport has utilized the intersection flow ratio to investigate that whether a large intersection becomes congested or not after implementing a two-level crossing with an exclusive over/underpass for small vehicles. Absolutely, it is also possible to judge the evaluation by using intersection flow ratio of large intersection, regardless its traffic condition being congested or not. However, in some cases, the flow ratio although is 0.9 or less that means no congestion, in fact the total travel time for all vehicles passing through the intersection is significantly increased. This is because the intersection is very congested, so the traffic cannot smoothly pass through (low traffic flow), and it generates very long queue extending to upstream junction. The misinterpreting for this point must be carefully considered. Traffic engineers must be sure that the intersection under the flow ratio equal to or lower 0.9 is really not congested traffic. Otherwise, they need to apply some methods to consider whether or not traffic queuing is extended to the upstream junction.

To compute the time required for passing through the intersection with an exclusive over/underpass for small vehicles, it needs to calculate the intersection delays.

In order to estimate the average delay at a signalized intersection, many models have been developed. One of well-known models is Webster's model, as shown in (1).

$$d_w = \frac{C(1-\lambda)^2}{2(1-\lambda\, x)} + \frac{x^2}{2q(1-x)} - 0.65\left(\frac{C}{q^2}\right)^{1/3} x^{(2+5\lambda)} \tag{1}$$

$C$: Cycle length [s]
$g$: Green Time [s]
$\lambda$: Split [s]
$q$: Traffic volume [v/s]
$S$: Saturation flow rate [v/s]
$x$: $q/\lambda\, S = (q/S)/(g/C)$

Under the oversaturated traffic condition, the estimation of intersection delays by Webster formula is impossible. Therefore, it is still vital to develop an evaluation method for exclusive over/underpasses under very congested condition in the further study. Not only Webster model was considered in the study, Kimber & Hollis model, an empirical delay curve, was taken into account for the oversaturated traffic conditions also. However, this study did not intend to compare Webster model with Kimber & Hollis model. This is because the delay formulation in Kimber & Hollis model does not clearly consider traffic-signalized intersection, for example, cycle of length and green time.

### 3.2 Evaluation of Intersection Based on Traffic Simulation

As explained before, the approach of intersection evaluation is appropriate for unsaturated traffic conditions only. Nonetheless, there are some additional important points that have to be taken into account. First, the mentioned evaluation method is applicable for an individual intersection only. When one evaluates an exclusive over/underpass passing over two or more intersections, the traditional one cannot evaluate its effectiveness. Second, it is necessary to clearly consider the proportion of large vehicles at an intersection, since a number of large vehicles can significantly influence the quality of service of at-grade intersection. These point out that the application of existing intersection evaluation is insufficient to evaluate an exclusive over/underpass.

To fulfill the mentioned weakness of existing method, this study proposes to apply dynamic micro traffic simulation software. The software helps to overcome all previously explained problems. Not only the oversaturated condition can be considered, but the systematical evaluation for a part of network including many vicinity intersections can be performed also. Various important quantitative parameters, such as travel time, delays, queue length, etc., are reported as informative data for the evaluation between with and without an over/underpass. The interaction between effected intersections is arisen into the evaluation as well.

To compare the results of Traditional Evaluation and Evaluation by Simulation, this research plans to conduct the evaluation of exclusive over/underpasses based on both two approaches. The details of evaluations can be demonstrated into Figure 3.

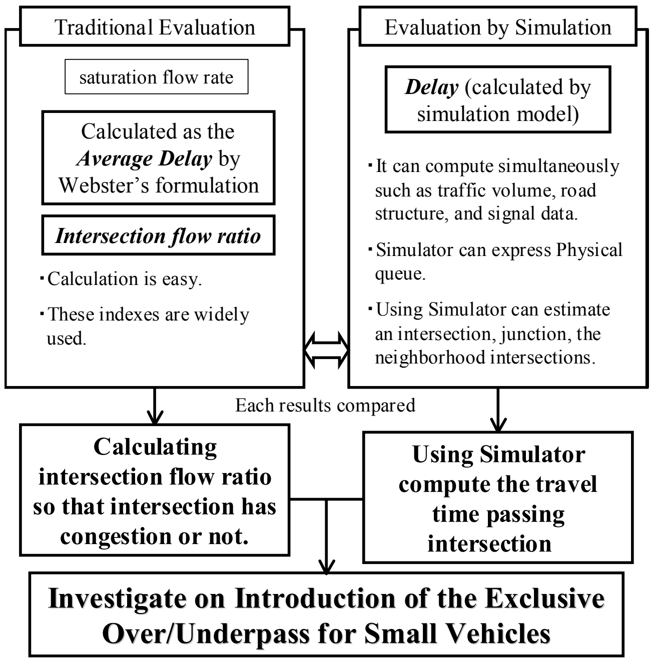



Figure 3. Estimation of introduction Over/underpass

In the Figure, both the evaluations of the at-grade intersection by Webster model and by simulation consider delays, but the intersection flow ratio must be estimated also for Webster model. Next, the travel time required for passing intersection before and after implementing the exclusive over/underpass is calculated. Normally, it should be decreased after the intersection established by an over/underpass. In addition, the influences of physical queue length probably affecting the upstream traffic should be concerned, particularly when it can be changed from time to time, as shown in Figure 4. It can be seen that this complicated situation is possible to be evaluated by the traffic simulation software. All effects of traffic situation and road physical structure are included into the evaluation, thus the accurate evaluation of effectiveness for exclusive over/underpass for small vehicles can be performed.

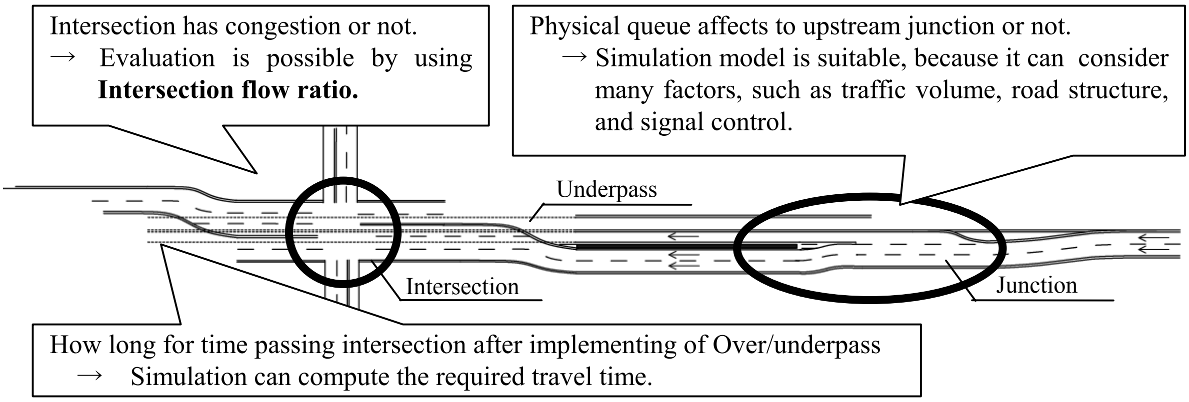



Figure 4. Complicated traffic conditions after implementing an underpass

## 4. ESTIMATION INTRODUCING THE EXCLUSIVE FOR SMALL VEHICLES

Two intersections in Chiba Prefecture were selected as case studies, called Case-01 and Case-02, to illustrate the evaluation of effects caused by an exclusive underpass for small vehicles. The layout of studied intersections and their traffic conditions can be shown in Figure 5, Table 2, and Table 3, respectively. PARAMICS, a worldwide simulation package, was utilized for this study, because of its various capabilities in simulating microscopic traffic conditions, such as lane changing modeling, intersection signalization, modeling for restriction of large vehicles, three-dimensions visualization etc. These were very useful in evaluating the effectiveness of introducing of an exclusive over/underpass for small vehicles.

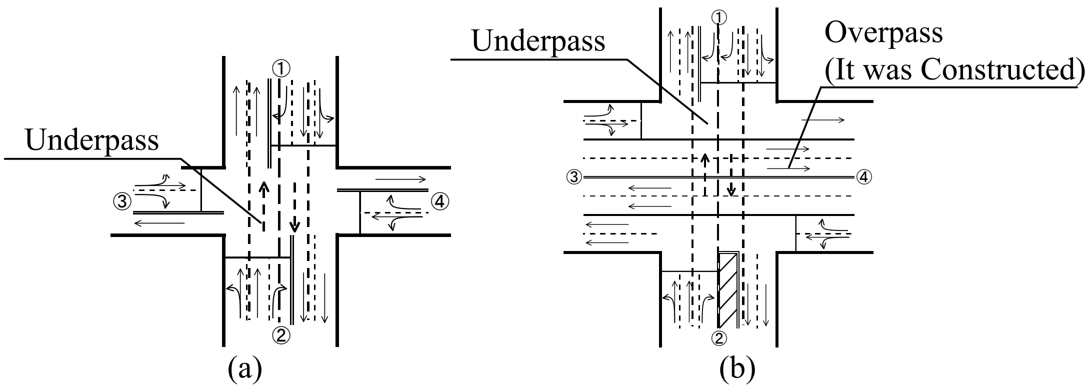



Figure 5. The layout of intersection (a) Case-01 and (b) Case-02.

Table 2 Traffic volume / congestion length (top : Case-01, bottom : Case-02)

| inflow | | ① | | | ② | | | ③ | | | ④ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| outflow | | left | straight | right | left | straight | right | left | straight | right | left | straight | right |
| 7:00-7:15 | traffic volume[v/15min] | 30 | 367 | 13 | 55 | 364 | 19 | 19 | 59 | 41 | 8 | 49 | 37 |
| | max congestion length[m] | 0 | | | 1800 | | | 0 | | | 150 | | |
| 7:15-7:30 | traffic volume[v/15min] | 28 | 380 | 21 | 53 | 383 | 13 | 7 | 63 | 34 | 2 | 63 | 40 |
| | max congestion length[m] | 0 | | | 1650 | | | 0 | | | 220 | | |
| 7:30-7:45 | traffic volume[v/15min] | 24 | 345 | 24 | 68 | 385 | 17 | 9 | 64 | 28 | 2 | 70 | 31 |
| | max congestion length[m] | 0 | | | 2650 | | | 0 | | | 190 | | |
| 7:45-8:00 | traffic volume[v/15min] | 39 | 316 | 21 | 74 | 376 | 15 | 9 | 64 | 28 | 5 | 63 | 31 |
| | max congestion length[m] | 0 | | | 3100 | | | 0 | | | 240 | | |
| 8:00-8:15 | traffic volume[v/15min] | 35 | 299 | 25 | 49 | 284 | 14 | 7 | 79 | 30 | 5 | 69 | 48 |
| | max congestion length[m] | 0 | | | 2700 | | | 0 | | | 120 | | |
| 8:15-8:30 | traffic volume[v/15min] | 31 | 291 | 20 | 55 | 273 | 19 | 4 | 69 | 34 | 6 | 70 | 46 |
| | max congestion length[m] | 0 | | | 3000 | | | 0 | | | 150 | | |
| 8:30-8:45 | traffic volume[v/15min] | 33 | 292 | 21 | 49 | 190 | 25 | 15 | 57 | 28 | 10 | 61 | 55 |
| | max congestion length[m] | 0 | | | 2650 | | | 0 | | | 0 | | |
| 8:45-9:00 | traffic volume[v/15min] | 38 | 282 | 11 | 49 | 229 | 30 | 24 | 130 | 64 | 10 | 65 | 37 |
| | max congestion length[m] | 0 | | | 2850 | | | 0 | | | 0 | | |

| inflow | | ① | | | ② | | | ③ | | | ④ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| outflow | | left | straight | right | left | straight | right | left | straight | right | left | straight | right |
| 7:00-7:15 | traffic volume[v/15min] | 28 | 316 | 73 | 20 | 442 | 26 | 36 | 372 | 34 | 17 | 333 | 43 |
| | max congestion length[m] | 1200 | | | 2800 | | | 0 | | | 100 | | |
| 7:15-7:30 | traffic volume[v/15min] | 28 | 321 | 97 | 14 | 463 | 26 | 44 | 344 | 37 | 18 | 360 | 57 |
| | max congestion length[m] | 1500 | | | 3400 | | | 0 | | | 150 | | |
| 7:30-7:45 | traffic volume[v/15min] | 30 | 400 | 58 | 18 | 387 | 17 | 42 | 357 | 50 | 21 | 356 | 66 |
| | max congestion length[m] | 1600 | | | 3200 | | | 0 | | | 200 | | |
| 7:45-8:00 | traffic volume[v/15min] | 30 | 364 | 45 | 17 | 393 | 18 | 42 | 340 | 47 | 13 | 414 | 61 |
| | max congestion length[m] | 1800 | | | 3000 | | | 0 | | | 150 | | |
| 8:00-8:15 | traffic volume[v/15min] | 32 | 383 | 61 | 13 | 329 | 15 | 51 | 364 | 50 | 22 | 427 | 46 |
| | max congestion length[m] | 1600 | | | 3200 | | | 0 | | | 100 | | |
| 8:15-8:30 | traffic volume[v/15min] | 38 | 334 | 33 | 17 | 276 | 13 | 35 | 340 | 49 | 26 | 346 | 63 |
| | max congestion length[m] | 2000 | | | 3800 | | | 0 | | | 100 | | |
| 8:30-8:45 | traffic volume[v/15min] | 37 | 352 | 44 | 31 | 310 | 24 | 31 | 332 | 54 | 30 | 367 | 66 |
| | max congestion length[m] | 2200 | | | 4200 | | | 0 | | | 150 | | |
| 8:45-9:00 | traffic volume[v/15min] | 27 | 363 | 52 | 20 | 267 | 28 | 18 | 308 | 50 | 28 | 383 | 41 |
| | max congestion length[m] | 2500 | | | 3400 | | | 0 | | | 100 | | |

Table 3 Parameters for signal control (left : Case-01, right : Case-02)

| Phase | 1φ | 2φ | 3φ | 4φ |
|---|---|---|---|---|
| Direction | | | | |
| green time[s] | 85 | 8 | 40 | 10 |
| amber[s] | 3 | 3 | 3 | 3 |
| cycle length[s] | 160 | | | |

| Phase | 1φ | 2φ | 3φ |
|---|---|---|---|
| Direction | | | |
| green time[s] | 92 | 19 | 31 |
| amber[s] | 4 | 3 | 3 |
| cycle length[s] | 160 | | |

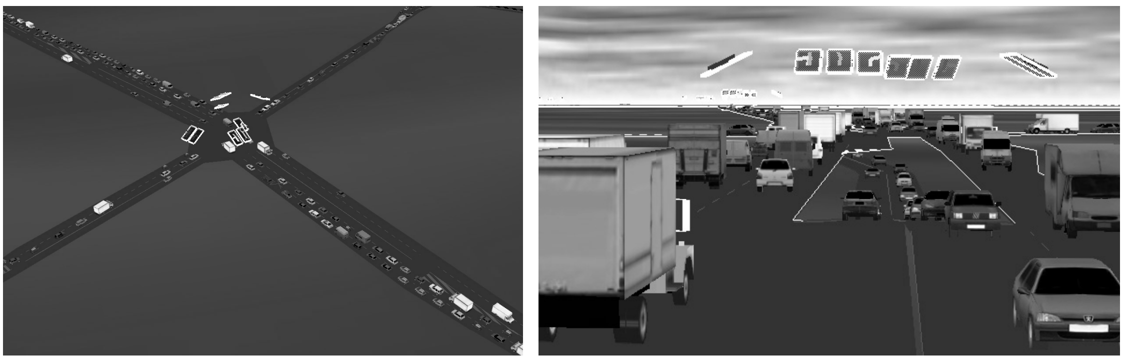


Figure 6. The visualization of simulation results in PARAMICS

With the powerful function in visualizing simulated traffic conditions, PARAMICS helps to obviously evaluate the performances of the exclusive over/underpass for small vehicles as shown in Figure 6. In Japan, an empirical study was conducted by employing PARAMICS, and its result has proved the significances of using traffic volume data in microscopic simulation model. Nevertheless, it was found that the existing study did not concern driving behaviors in the model. Therefore, to include the driving behaviors in the simulation, this study modeled the behaviors through setting up various PARAMICS parameters, consisting of speed limit of link, gradient of link, number of lane, length of lane, cycle length, green time, mean reaction time and mean headway. Furthermore, the specific parameters reflecting the actual traffic situation were also considered based on the observed traffic data, including traffic volume and mean travel time passing through each intersection.

At first, the existing evaluation method and the adjustment of evaluation by simulation are verified. Both the delay by Webster formula and intersection flow ratio were calculated, and compared with the average delay from the simulation results. The study wants to check that the results from both approaches are the same or not. Furthermore, the variation of traffic volume is also included to determine the effects of traffic conditions on the quality of service of the exclusive underpass. The traffic capacity of intersection was referred as 100 %, then it would be varied into several conditions to consider the effects as shown in Table 4.

Table 4. The results of Webster formula and simulations (a) Case-01 and (b) Case-02

| total traffic volume [%] | intersection flow ratio | webster $d_w$ [s] | simulation $d_s$ [s] | $d_w$-$d_s$ [s] |
|---|---|---|---|---|
| 70 | 0.64 | 34.4 | 35.5 | -1.1 |
| 75 | 0.68 | 36.0 | 36.4 | -0.4 |
| 80 | 0.73 | 38.3 | 39.4 | -1.1 |
| 85 | 0.77 | 42.4 | 42.9 | -0.5 |
| 90 | 0.82 | 57.6 | 54.7 | 2.9 |
| 95 | 0.86 | * | 70.0 | |
| 100(present) | 0.91 | * | 81.4 | |

$* \; x = q/\lambda S$ more than 1

(a)

| total traffic volume [%] | intersection flow ratio | webster $d_w$ [s] | simulation $d_s$ [s] | $d_w$-$d_s$ [s] |
|---|---|---|---|---|
| 70 | 0.63 | 32.5 | 31.5 | 1.0 |
| 75 | 0.67 | 33.6 | 32.8 | 0.8 |
| 80 | 0.72 | 34.8 | 34.1 | 0.7 |
| 85 | 0.76 | 36.1 | 36.0 | 0.1 |
| 90 | 0.81 | 37.7 | 38.2 | -0.5 |
| 95 | 0.85 | * | 42.1 | |
| 100(present) | 0.90 | * | 46.3 | |

$* \; x = q/\lambda S$ more than 1

(b)

As the results, the average delays estimated by Webster formula and by the simulations in Case-01 and Case-02 were almost the same. However, in the case that the traffic flow ratio higher than 95 %, the average delays of Webster formula were decreased. This did not represent the realistic situation. The delays were decreased in Webster model, because when traffic volume exceeding the saturation flow rate ( $x$ >1.00), the second term of formula became the negative value. Thus, the magnitude of average delays was reduced. Under the same oversaturated situation, the average delay calculated by using the simulation had tendency to be considerably increased as the effects of accumulated traffics. There was no doubt that the results of simulations could stand for more realistic traffic conditions.

Second, the implementations of an exclusive over/underpass for small vehicles and for all vehicles in Case-01 and Case-02 were evaluated. The intersection flow ratio, time for passing the intersection, and rate of reduced time, could be estimated and summarized into Table 5. To calculate the rate of reduced time, the equation (2) and (3) were utilized as shown in the following;

$$R_s = \frac{T_p - T_s}{T_p} \times 100 \ \ (\%) \tag{2}$$

$$R_f = \frac{T_p - T_f}{T_p} \times 100 \ \ (\%) \tag{3}$$

$R_s$ : Rate of reduced passing intersection time required by an implementing exclusive underpass for small vehicles (%).

$R_f$ : Rate of reduced passing intersection time required by an implementing underpass for all vehicles (%).

$T_p$ : Average passing intersection time required at present [s/v]

$T_s$ : Average passing intersection time required after an implementing exclusive underpass for small vehicles [s/v]

$T_f$ : Average passing intersection time required after an implementing underpass for all vehicles [s/v]

Table 5. The results of simulation model introduction over/underpass.

| | | | Case-01 | Case-02 |
|---|---|---|---|---|
| Intersection flow ratio | | | | |
| | Present | $\rho_p$ | 0.91 | 0.90 |
| | Implementing Exclusive Over/Underpass for small vehicles | $\rho_s$ | 0.63 | 0.74 |
| | Implementing Over/Underpass for all vehicles | $\rho_f$ | 0.47 | 0.44 |
| Time required passing intersection [s/v] | | | | |
| | Present | $T_p$ | 83.1 | 48.6 |
| | Implementing Exclusive Over/Underpass for small vehicles | $T_s$ | 54.4 | 12.6 |
| | Implementing Over/Underpass for all vehicles | $T_f$ | 41.4 | 11.9 |
| Rate of reduced time required[%] | | | | |
| | Implementing Exclusive Over/Underpass for small vehicles | $R_s = (T_p\text{-}T_s)/T_p \times 100$ | 34.5 | 73.3 |
| | Implementing Over/Underpass for all vehicles | $R_f = (T_p\text{-}T_f)/T_p \times 100$ | 50.2 | 74.8 |

From Table 5, it was noticed that the time for passing intersection could be reduced significantly for both case studies that established by the exclusive underpass for small vehicles, as seen from the 34.5 % and 73.3 % reduction, respectively. Definitely, by the high capacity of larger structure the underpass for all vehicles should be able to decreased the time more than the one of small vehicles. However, traffic engineers have to consider about the cost effectiveness for such facilities also. With higher costs about 30 %, the underpass of all vehicles could reduce the time 15.7 % (50.2-34.5) for Case-01, and only 1.5 % (74.8-73.3) for Case-02. This points out that the underpass for small vehicles is very effectiveness in term of congestion alleviation and construction cost. Next, the sensitivity analysis was carried out to determine the effects of rate of total traffic volume and rate of large vehicles as shown the results in Table 6 and 7 and Figure 7 and 8.

As shown by the results, when the rate of large vehicles in the flow was low and traffic flow was not so much, the efficiencies of an exclusive underpass for small vehicles and for all vehicles were insignificantly different. However, if the proportion of large vehicles was increased for the underpass of small vehicles, its efficiency in reducing the time obviously decreased. As can be seen that at higher than 30 % of large vehicles in traffic, the percentages of time reduction was significantly decreased (see Figures 7 (a) and 8 (a)). This shows that the effective operational condition of an exclusive underpass should be limited under the low proportion of large vehicles. In the case that it cannot control large vehicles, the situation can be improved by changing geometric designs of intersection. In particular, the modification of geometric designs or physical conditions of underpasses for small vehicles is much easier than in the case of underpasses for all vehicles such as the modification of bridge pier structure etc.

Consider the comparison of simulation results between Case-01 and Case-02, it was found that as none of vicinity intersections in Case-01 was implemented for an underpass, thus it had the effects on reducing total travel time passing through the intersection by regardless of traffic volume or large vehicle ratio. On the other hand, in Case-02 there was a nearby intersection introduced by an underpass, so the neighborhood-signalized intersections become the new bottlenecks. More congested traffic condition in the neighborhood-signalized intersections was occurred, because the traffic volumes approaching to such intersections had been increased. This is an interesting point that should be investigated for evaluating the implementation of over/underpasses through a multi intersection analysis likes Case-02.

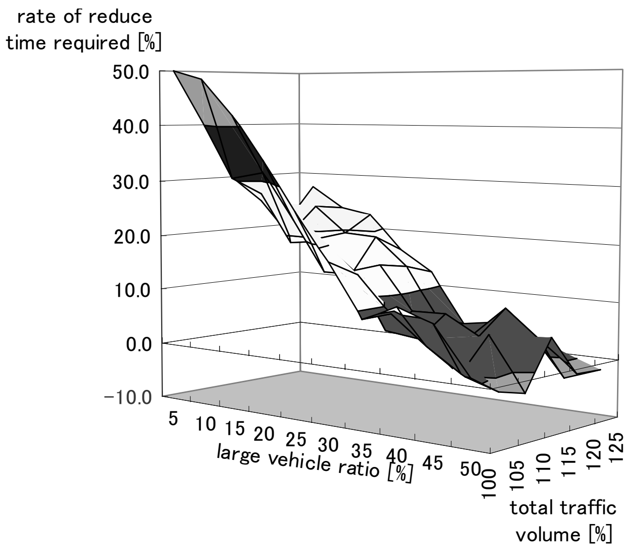
Table 6. The intersection flow ratio by implementing over/underpass for Case-01 (a) exclusive for small vehicles and (b) for all vehicles.

| | | total traffic volume [%] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 | 105 | 110 | 115 | 120 | 125 |
| large vehicle ratio [%] | 5 | 0.50 | 0.52 | 0.55 | 0.57 | 0.59 | 0.62 |
| | 10 | 0.54 | 0.57 | 0.60 | 0.62 | 0.65 | 0.68 |
| | 15 | 0.59 | 0.62 | 0.65 | 0.68 | 0.71 | 0.73 |
| | 20 | 0.63 | 0.66 | 0.70 | 0.73 | 0.76 | 0.79 |
| | 25 | 0.68 | 0.71 | 0.74 | 0.78 | 0.81 | 0.84 |
| | 30 | 0.72 | 0.75 | 0.79 | 0.83 | 0.86 | 0.90 |
| | 35 | 0.76 | 0.80 | 0.83 | 0.87 | 0.91 | 0.94 |
| | 40 | 0.80 | 0.84 | 0.88 | 0.92 | 0.96 | 1.00 |
| | 45 | 0.84 | 0.88 | 0.92 | 0.97 | 1.01 | 1.05 |
| | 50 | 0.89 | 0.93 | 0.97 | 1.02 | 1.06 | 1.10 |

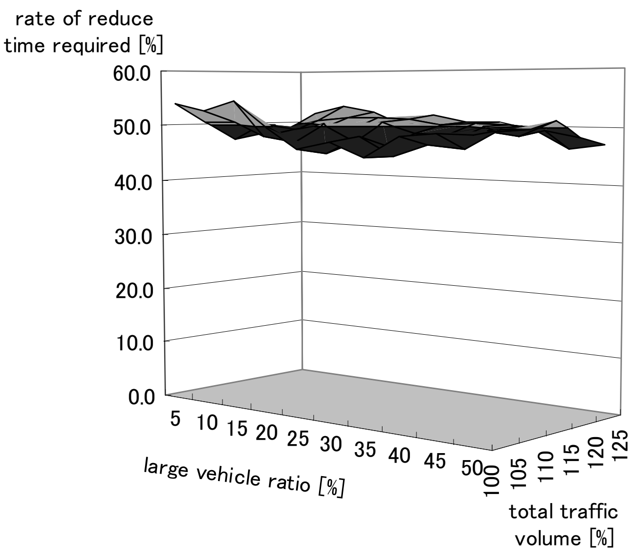
(a)

| | | total traffic volume [%] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 | 105 | 110 | 115 | 120 | 125 |
| large vehicle ratio [%] | 5 | 0.45 | 0.47 | 0.49 | 0.52 | 0.54 | 0.56 |
| | 10 | 0.46 | 0.48 | 0.50 | 0.53 | 0.55 | 0.57 |
| | 15 | 0.47 | 0.49 | 0.51 | 0.54 | 0.56 | 0.58 |
| | 20 | 0.47 | 0.50 | 0.52 | 0.54 | 0.57 | 0.59 |
| | 25 | 0.48 | 0.51 | 0.53 | 0.55 | 0.58 | 0.60 |
| | 30 | 0.49 | 0.51 | 0.54 | 0.56 | 0.59 | 0.61 |
| | 35 | 0.50 | 0.52 | 0.55 | 0.57 | 0.60 | 0.62 |
| | 40 | 0.51 | 0.53 | 0.55 | 0.58 | 0.61 | 0.63 |
| | 45 | 0.51 | 0.54 | 0.56 | 0.59 | 0.62 | 0.64 |
| | 50 | 0.52 | 0.55 | 0.57 | 0.60 | 0.63 | 0.65 |

(b)




(a)




(b)

Figure 7. The rate of reduced time for passing intersection for Case-01 (a) exclusive for small vehicles and (b) for all vehicles.

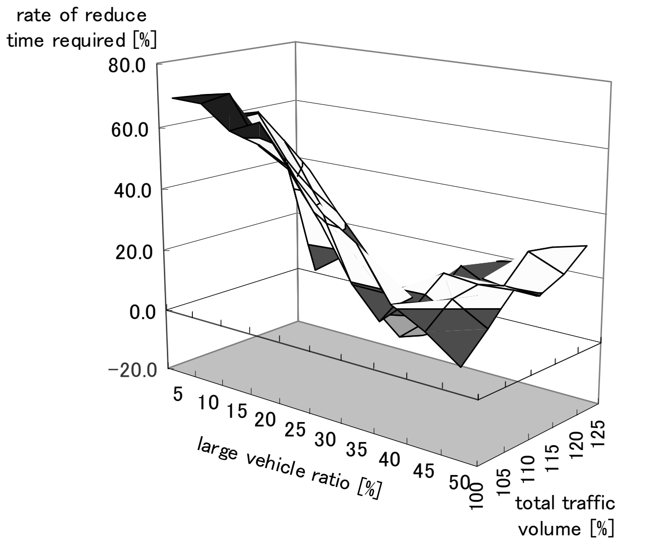
Table 7. The intersection flow ratio by implementing over/underpass for Case-02 (a) exclusive for small vehicles and (b) for all vehicles.

| | | total traffic volume [%] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 | 105 | 110 | 115 | 120 | 125 |
| large vehicle ratio [%] | 5 | 0.44 | 0.46 | 0.49 | 0.51 | 0.53 | 0.55 |
| | 10 | 0.54 | 0.56 | 0.59 | 0.62 | 0.64 | 0.67 |
| | 15 | 0.64 | 0.67 | 0.70 | 0.73 | 0.76 | 0.80 |
| | 20 | 0.74 | 0.77 | 0.81 | 0.85 | 0.88 | 0.92 |
| | 25 | 0.84 | 0.88 | 0.92 | 0.96 | 1.00 | 1.04 |
| | 30 | 0.93 | 0.98 | 1.03 | 1.07 | 1.12 | 1.17 |
| | 35 | 1.03 | 1.09 | 1.14 | 1.19 | 1.24 | 1.29 |
| | 40 | 1.14 | 1.19 | 1.25 | 1.31 | 1.36 | 1.42 |
| | 45 | 1.23 | 1.29 | 1.36 | 1.42 | 1.48 | 1.54 |
| | 50 | 1.34 | 1.41 | 1.46 | 1.53 | 1.60 | 1.66 |

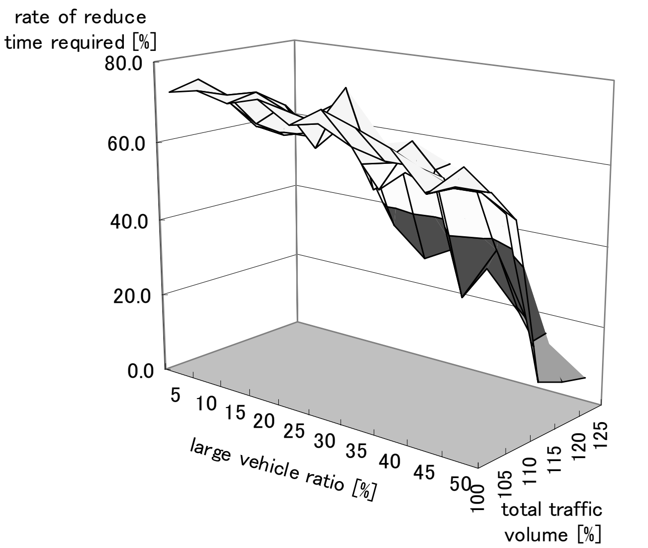
(a)

| | | total traffic volume [%] | | | | | |
|---|---|---|---|---|---|---|---|
| | | 100 | 105 | 110 | 115 | 120 | 125 |
| large vehicle ratio [%] | 5 | 0.40 | 0.41 | 0.43 | 0.45 | 0.47 | 0.49 |
| | 10 | 0.41 | 0.43 | 0.44 | 0.46 | 0.48 | 0.50 |
| | 15 | 0.43 | 0.44 | 0.46 | 0.48 | 0.50 | 0.52 |
| | 20 | 0.44 | 0.46 | 0.47 | 0.49 | 0.52 | 0.54 |
| | 25 | 0.46 | 0.47 | 0.49 | 0.51 | 0.53 | 0.55 |
| | 30 | 0.47 | 0.48 | 0.50 | 0.52 | 0.55 | 0.57 |
| | 35 | 0.48 | 0.50 | 0.51 | 0.54 | 0.56 | 0.58 |
| | 40 | 0.50 | 0.51 | 0.53 | 0.55 | 0.58 | 0.60 |
| | 45 | 0.51 | 0.53 | 0.54 | 0.57 | 0.59 | 0.62 |
| | 50 | 0.52 | 0.54 | 0.56 | 0.58 | 0.61 | 0.64 |

(b)




(a)




(b)

Figure 8. The rate of reduced time for passing intersection for Case-02 (a) exclusive for small vehicles and (b) for all vehicles.

## 5. CONCLUSION

This study has investigated costs and the effects of implementing an exclusive over/underpass for small vehicles. The results pointed out that with the similar effectiveness in relieving traffic congestions, the exclusive over/underpass for small vehicles could be implemented by the construction costs much lower than in the case of over/underpasses for all vehicles. Therefore, it can be concluded that it is effective to construct exclusive over/underpasses for small vehicles in relieving traffic congestion in the network.

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