EVALUATION OF PUBLIC TRANSPORT POLICY BY MICROSCOPIC SIMULATION MODEL*

by Madhu ERRAMPALLI**, Masashi OKUSHIMA*** and Takamasa AKIYAMA****

1. Introduction

Since two decades, simulation technique has been widely used to analyze vehicle operations under different policy measures to evaluate their effectiveness. Microscopic simulation analysis has received higher attention in the last decade because they try to analyze each individual vehicle behavior and are capable of using behavioral models that can account for drivers' reactions.

Though, many researchers all over the world have developed microscopic simulation models, there is an absence of sophisticated model to evaluate especially public transport policy measures. Hence, an attempt has been made in this study to develop a microscopic simulation model to evaluate different public transport policies particularly public transport priority systems (PTPS) as a primary objective. The following two types of public transport policies have been considered for evaluation. They are:

- Bus lanes i.e. special lanes dedicated to buses to insure high quality transit service and
- Public transport priority system at traffic signals i.e. signals would be set to green which allows a bus to avoid stopping.

Another objective of the present study is also to incorporate fuzzy logic reasoning in route choice behaviour based on the possibility index of the available routes.

2. Development of Microscopic Simulation Model

(1) Model Structure

The basic components and processes involved in developing microscopic simulation model have been given in the form of flow chart in Figure 1. Initially vehicles would be generated on the network from the vehicular, OD and network data and then route would be assigned after that. Vehicular movements would be estimated from the traffic models such as car-following and lane changing. The formulations involved in the models such as car-following, lane change and route choice model have been described in brief in the following sections. In this model, private cars, heavy vehicles and buses have been considered.

*Key Words: microscopic traffic simulation, public transport priority system (PTPS), bus lanes, fuzzy logic route choice
**Doctoral Student, E-mail: k3812105@guedu.cc.gifu-u.ac.jp
***Research Associate, E-mail: okushima@cc.gifu-u.ac.jp
****Professor, E-mail: takamasa@cc.gifu-u.ac.jp
Department of Civil Engineering, Gifu University, 1-1, Yanagido, GIFU 501-1193, Japan,
Tel: +81-58-293-2446, Fax: +81-58-230-1528

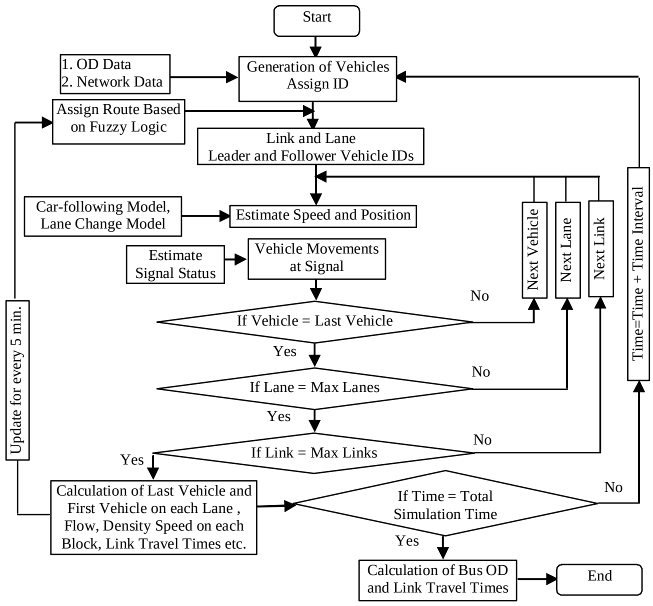

Figure 1: Flow Chart for the Present Microscopic Simulation Model

(2) Car-following Model

This model describes the movement of individual vehicles within a platoon and two different conditions can be conceived by each vehicle at any time. They are the intention of a vehicle to achieve desired speed while there is no leader vehicle and limitations imposed by the leader vehicle to travel at desired speed. The formulation for first condition has been considered from the Gipps model[1)]. In case of second situation, Hidas car-following formulation[2)] has been considered. From these two formulations, acceleration for a vehicle can be determined in all the situations. And then the position of vehicle is updated from the acceleration in every time interval.

(3) Lane Change Model

In the present model, lane changing phenomenon has been considered for the purposes of turn type at next intersection, speed advantage and traffic management measures such as bus lane policy. The process of lane change includes estimation of purpose, target lane, necessity level and feasibility. The feasibility would be checked based the gap availability in the target lane.

If the situation is not feasible to change a lane though the necessity level is must, then courtesy lane change would be applied. In the courtesy lane change model, courtesy giver vehicle would be identified in the target lane and it will forcibly decelerate till the sufficient gap is created to carry out the lane change process by subject vehicle[3)]. The sequential processes involved in the lane change model have been explained pictorially in Figure 2.

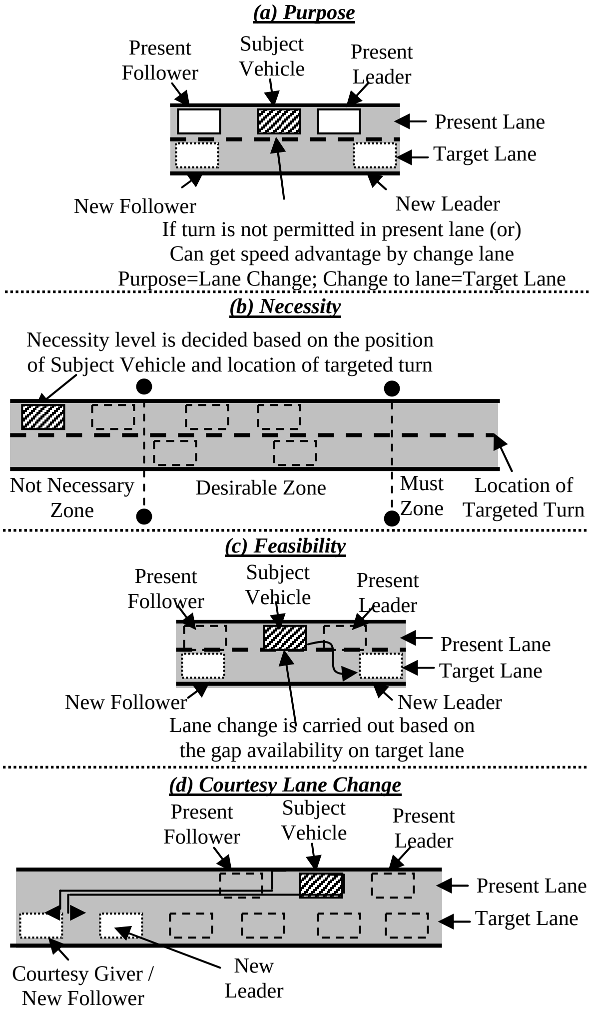

Figure 2: Processes involved in Lane Change Model

(4) Route Choice with Fuzzy Logic

In this model, fuzzy logic is considered in route choice analysis. It is assumed that drivers choose their route based on possibility index, which represents the possibility of choosing that route. To compare the possibility indexes of all available routes, it is necessary to have a fuzzy goal function (F_g)[4] as shown in the Figure 3.

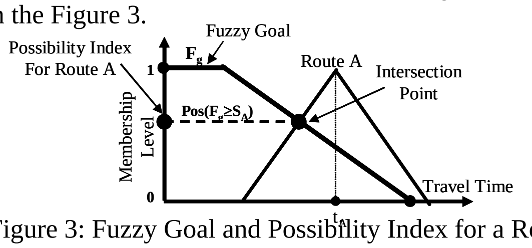

Figure 3: Fuzzy Goal and Possibility Index for a Route

The route travel time is considered as triangular fuzzy number as shown in the figure. The possibility index for a route is the superior of the minimum of membership functions of fuzzy goal and route travel time and in other words it is the intersection point of these two curves i.e. fuzzy goal line and route fuzzy membership function[5] as shown in Figure 3. The possibility indexes for all the available routes have been calculated and finally driver selects the route, which has maximum possibility index.

3. Validation of Microscopic Simulation Model

For the validation purpose, a part of Gifu city network has been considered consisting of 60 nodes and 204 links has been presented in Figure 4. Each link assumed to be having two lanes in both directions. In this study, the fuzzy route travel times have been calculated for the three alternative routes; they are shortest path by distance, by time and dynamic shortest path. The possibility indexes for these three routes have been calculated and finally driver selects the route, which has maximum possibility index. In this study, a constant cycle length has been considered for all the intersections (4 and 3 arm) i.e. 120 sec.

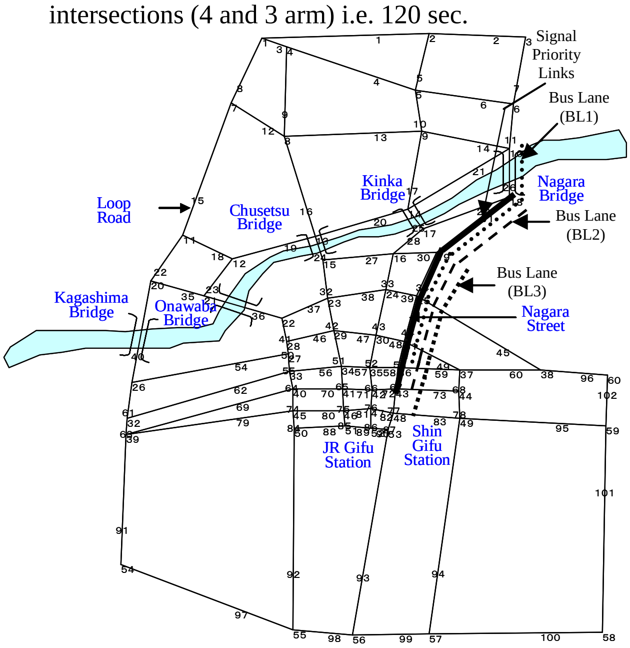

Figure 4: Part of Gifu City Network Considered for Application of Simulation Model

The vehicle movements have been estimated for 3 hours (from 06:30 to 09:30) using the developed microscopic simulation model and calculated peak hour link flows. After the thorough investigation, the observed peak hour link flows in the field for certain links of the Gifu city network have been obtained from the reliable sources. These values have been used here to validate the present simulation model. The comparison between observed and simulated values has been shown in Figure 5 for about 115 links spreading through out the network.

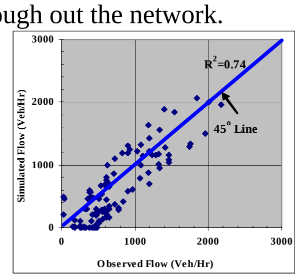

Figure 5: Comparison of Observed and Simulated Link Flows to Validate Microscopic Simulation Model

From the statistical analysis, it has been found that R^2 is 0.74 with RMS value about 301 Veh/Hr and. Therefore, it can be said that the developed simulation model is able to predict the vehicular movements with a fair amount of accuracy.

4. Public Transport Policy

(1) Bus Lane Policy

In the present study, bus lanes have been assumed to be introduced in some part of the links on the Nagara Street to ensure high quality of service for buses as shown in Figure 4. Out of the two lanes, left lane has been considered as bus lane. Only buses are permitted to use this lane and other vehicles will change their lane from existing lane to adjacent lane. The simulation model has been applied by including and excluding bus lanes and compared the cases to evaluate the policy. OD, Link Travel time for buses and other vehicles and total travel time have been considered as parameters of evaluation. This policy is introduced in three different sets of links from north to south directions (BL1 Set – Link No. 26, 133, 34, 44 and 53; BL2 Set – Link No. 133, 34, 44, 53 and 67; BL3 Set – Link No. 34, 44, 53, 67 and 77) only and estimated the results using developed microscopic simulation model.

The comparison of typical OD and link travel times for existing (without bus lanes) and with bus lane policy has been presented in Figure 6 and 7 for different bus lane options. From these figures, it can be observed that a maximum of about 19% and 2% of reductions in OD and link travel times respectively. In case of other vehicles, a maximum of about 19% and 37% of increase in OD and link travel times respectively can be found. It can be observed from the figures that the OD and link travel time has increased due to the implementation of bus lanes resulting increase in congestion on other than bus lane. Hence the total travel time has increased and vehicles also changed their route to avoid bus lanes in case of implementation of bus lane policy.

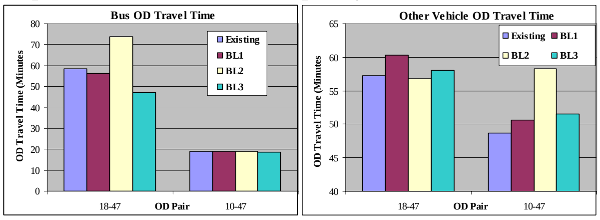

Figure 6: Comparison of OD Travel Times for Existing and Bus Lane Policies for Typical OD Pairs

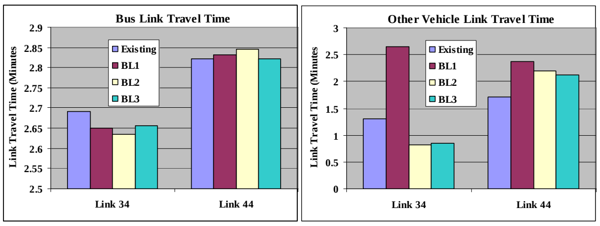

Figure 7: Comparison of Link Travel Times for Existing and Bus Lane Policy for Typical Links

The comparison of total travel time and total number of vehicles using the links having bus lane between 07:00 and 09:00 in all the cases (BL1, BL2 and BL3) with existing case have been presented in Table 2. The maximum of about 18% vehicles changed their route and total travel time has increased about 3% in the two hours duration i.e. from 07:00 to 09:00. From these results it can be said that, the option BL3 is likely to draw maximum benefits in terms of reducing travel times of buses and judiciously adjusting the other vehicles' travel time, total travel time and number of vehicles changing their route.

Table2: Comparison of Total Travel Time and Vehicles Using Bus Lane under Different Options of Bus Lane Policy

Option	Total Travel Time (Hours)	Number of Vehicles using Bus Lane
BL1	18942.84 *(3.1%)*	4017 *(-18.0%)*
BL2	18663.95 *(1.6%)*	4003 *(-18.26%)*
BL3	18118.54 *(1.4%)*	4173 *(-14.8%)*

Note: Values in parenthesis represents percentage change from exiting condition

(2) PTPS at Intersections

Public transport priority system (PTPS) can be given by introducing new priority signal phase, which allows a bus to avoid stopping at traffic signal. The considered intersections to introduce priority are at Node No. 19, 25, 31, 36 and 43 as shown in Figure 4. the priority phase has been assumed in the north to south and south north directions. The links falls under priority are Link No. 34, 44, 53, 67, 133, 136, 146, 155, 169 and 179. In the present study, priority phase has been introduced whenever the bus nears the intersection on these links. When the priority is introduced on these links non priority phase has been initiated on the crossing links at the above mentioned intersections. The links falls under crossing links category are Link No. 30, 39, 48, 58, 72, 147, 151, 161 and 175. Three types of priority options have been evaluated and they have been given in the Table 3.

Table 3: Types of Signal Priority Policy Options Considered for Evaluation

Option	Cycle Length	Priority Phase Description
PR1	Constant (120 Sec)	Restarting with Green
PR2	Depends on Approach Volume	Restarting with Green
PR3	Depends on Approach Volume	Extending Green till Priority Vehicle Cross (Or) Curtail Red and Make it Green to Cross the Priority Vehicle

The results have been estimated using developed microscopic simulation model. The parameters considered to evaluate this policy are same as evaluation of bus lane policy. They are OD, Link Travel time for buses and other vehicles and total travel time. The comparison of typical OD and link travel times for existing (without PTPS policy) and with PTPS policy has been presented in the Figure 8 and Figure 9 respectively. From the figures, it can be observed that a maximum of about 76% and 48% reduction in bus OD and link travel times respectively.

In case of other vehicles, a maximum of about 59% and 85% of decrease in OD and link travel times respectively can be found.

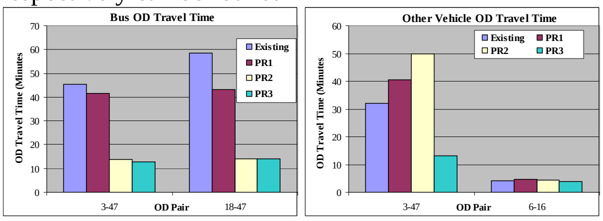

Figure 8: Comparison of OD Travel Times for Existing and Signal Priority Policies for Typical OD Pairs

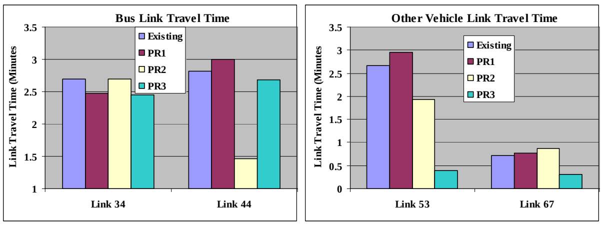

Figure 9: Comparison of Link Travel Times for Existing and Signal Priority Policies for Typical Links

The comparison of total travel time and total number of vehicles using the links having signal priority between 07:00 and 09:00 in all the cases (PR1, PR2 and PR3) with existing case have been presented in Table 4.

Table 4: Comparison of Total Travel Time and Vehicles Using Priority Lane under Different Options of Signal Priority Policy

Option	**Total Travel Time (Hours)**	**Number of Vehicles using Signal Priority Lanes**
PR1	18663.44 *(-1.6%)*	4698 *(4.16%)*
PR2	29928.78 *(-63.0%)*	10746 *(-119.4%)*
PR3	26420.91 *(-43.9%)*	2883 *(41.1%)*

Note: Values in parenthesis represents percentage change from exiting condition

The total travel time has increased about a maximum of 62% and more than double of the vehicles changed their route to priority links than existing. From the results it can be said that, the option PR3 is likely to draw maximum benefits in terms of reducing OD and link travel times of buses and judiciously adjusting the other vehicles' OD and link travel times, total travel time and number of vehicles changing their route.

5. Concluding Remarks

In this study, a microscopic simulation model has been formulated by considering car-following, lane changing models and tried to evaluate different public transport policies particularly public transport priority systems (PTPS). The main conclusions from this study can be summarized as given below:

- A microscopic simulation model has been developed to evaluate the public transport policies such as public transport priority systems (PTPS).
- Fuzzy logic reasoning has been incorporated in choosing the route by the drivers.
- The developed simulation model has been applied on the part of Gifu city network and it is able to predict the vehicular movements with a fair amount of accuracy.
- Two types of public transport policies have been considered for evaluation and they are: bus lanes and bus priority at traffic signal
- Three different options in Bus lane policy and in PTPS policy have been evaluated by microscopic simulation model
- It can be observed from the results that option BL3 and option PR3 are likely to draw maximum benefits in terms of reducing OD and link travel times of buses and judiciously adjusting the other vehicles' OD and link travel times, total travel time and number of vehicles changing their route.

From this study, it can be concluded that the developed microscopic simulation model can be applied to evaluate public transport polices particularly bus lane and PTPS at intersections with fair amount of accuracy.

In continuation of this study, it is proposed to consider mode choice behvaiour in the simulation model explicitly to evaluate the public transport improvement policies. For this purpose, generation of commuters on the network has to be considered. And incorporation of departure time model to analyze commuter's characteristics in starting their trips is also proposed. Along with that, it is proposed to consider modeling the commuters' behaviour related to information provision in the simulation model. With these improvements in the simulation model, it can be used to evaluate various types of travel demand management policies.

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