EFFECTIVENESS OF A BUS-PRIORITY LANE AS A COUNTERMEASURE FOR CONGESTION

By

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ABSTRACT

The main objective of this research is to identify the effectiveness of the bus priority lane in Shizuoka City as a countermeasure for traffic congestion. Shizuoka City, the capital of Shizuoka Prefecture in Japan suffers from frequent traffic congestion. To tackle this problem, authorities of Shizuoka City tested as a pilot project and have been implemented the BRT strategies. This project included the bus priority lane along a 3-km segment and the bus priority signal system. The data was mainly obtained trough traffic surveys, bus surveys, and questionnaire surveys which were conducted by author and Shizuoka city. All these surveys were carried out twice, before and after the implementation of BRT. After introducing priority treatments, there was a reduction in number of vehicles using main road. Also queue lengths and jam length measurements showed signs of easing of traffic congestion, and travel times of general vehicles were improved. Although the change associated with total travel time of buses was statistically not significant, but it still showed a reducing trend. But travel times of buses excluding dwelling times showed a significant reduction. The difference of significance associated with above travel parameters was mainly caused by increase incurred on dwelling times of buses. There were evident that the smoothness of traffic flows along bus lane as well as along general traffic lane was improved by the BRT project.

INTRODUCTION

Ground transportation throughout the world suffers from the problem of traffic congestion. During the past few decades, the public transport systems in major cities have seen a decrease in passenger ridership while personal automobiles have gradually emerged as the most popular means of transportation (*1,2*). This trend creates overcrowded and overburdened road networks. Transport planners adopt a variety of strategies to cope with this situation. Bus Rapid Transit (BRT) is a car-competitive service that public-transport planners have tried in their attempts to win back customers (*3,4*). The aim of this research is to identify the effectiveness of the bus-priority lane in Shizuoka City as a countermeasure for traffic congestion and the modal shifting of transport options.

FEATURES OF SHIZUOKA CITY

Profile of Shizuoka City

Shizuoka City (*5*) is located almost in the geographic center of Japan and had a population of approximately 700,000 with a density of 510 persons/km^2. It covers a total land area of 1,374 square kilometers, making it Japan's largest city, in terms of land area. Shizuoka City is the capital city as well as the core city of Japan's Shizuoka Prefecture. Its population is also dense, as compared with other cities in the Prefecture. On April 1, 2005, Shizuoka City was designated an ordinance city. This makes Shizuoka City Japan's 14th Metropolitan City; it joins Japan's club of mega cities that includes Tokyo, Osaka, and Yokohama. The designation as an ordinance city allows the city government to offer its residents a wide range of services. Furthermore, Shizuoka lies on the nation's main transport route, National Route No. 1, and the Tokaido Shinkansen Line (Super Express) and Tokaido line connect to Japan's major economic centers: Tokyo and Nagoya.

Transportation Characteristics of Shizuoka City

The car (*6,7*) is the dominant transportation mode, used for more than half of all personal trips in every trip category, except for commuter (student). For commuter (student) trips, walking is the main mode of travel, with a 55.3% share. Bike & cycle play a significant role in commuter (student) trips, comprising 24.8%. The car a remarkable 85.9% share of trips in the business category, while contributing 60%, 50.4%, and 54.9% shares to the commuter (worker), going home and private categories, respectively. The railway has 8.7% and 9.4% shares of the commuter (worker) and commuter (student) categories, respectively. Walking has a significant share of going home and private category trips, contributing 18.9% and 19.1%, respectively. Buses have the lowest share in every category.

+++ insert FIGURE 1 around here +++

Shizuoka City has a comparatively better bus service than other cities in Shizuoka Prefecture. If offers especially dense coverage within Central Shizuoka, which helps build a customer base for bus transit. This is demonstrated by the modal share statistics for the prefecture. The Shizuoka City Bus Service has a 3.5% share of total individual travel trips. The bus-transport network is most dense in the northern area near the train station. For example, the section before the Egawa-cho Intersection of prefectoral Road No. 27 (Road-27) provides 90 buses during the period of 0700 to 0800 on weekdays. During the day, buses originating from a number of different points in Shizuoka City ply Road-27 with a variety of frequencies and schedules. Their frequencies vary from every three to 12 min during peak morning hours, to every 15–25 min in off-peak times. Most of these lines terminate at either the Shizuoka JR station or Shin-Shizuoka Station. Because of this excellent service, Shizuoka City has the potential for being a good candidate for bus-priority treatment.

As Shizuoka's main commercial, financial, and political districts are concentrated on the north side of the train station, that area becomes the prefecture's nerve center. Road-27 serves this area, providing access for the important locations, such as the prefecture and city offices, the central hospital, post office, police station, primary and junior high school, and the public park and castle.

Though there is no continuous alternative route for Road-27 from its starting point, Road-74, which starts from Road-27 at the Sakura Toge Minami intersection (IS) is an alternate for Road-27. Road-74 runs along the east side of Road-27; it crosses National Route No. 01 (bypass) and finally intersects the southern branch of National Route No. 01, about 3 km from Shizuoka Station. On the west side of Road-27, there is no direct alternate route because of the Abe River, which flows along its west side. If a driver needs an alternate route, he must combine several routes such as Road-29, Road-362, and –354, or follow some other, minor routes.

+++ insert FIGURE 2 around here +++

Problem Identification

Shizuoka City suffers from congestion during morning peak hours, especially on weekdays from 0730–0900. Congestion becomes severe over time, and nowadays, long lines and traffic jams are common on most of the major roads leading to central Shizuoka. In some locations, the lines exceed three hundred meters and vehicles have to stay for several traffic-signal cycles to make it through an intersection. Congestion becomes more severe at Shofu intersection on Road-27, where line lengths reach 860 m during morning rush hours. As Shizuoka City's economy is heavily dependent on the service sector, worsening congestion can paralyze the economy of the entire prefecture.

The public-transport sector also suffers from traffic congestion. Recent trends associated with the public-transport sector give warning signs regarding their future. JR rail has been losing patronage since 1996. In 1996, the JR lines had an average of 156,000 passengers per day. This number dropped gradually down to 147,000 in 2000. This situation is also seen with Shin Shizuoka Rail (Shizuoka Railway Company) since 1991. It had 41,000 passengers per day in 1991, and this decreased to 33,000 in 2000. This same problem is more significant for bus companies than rail. During the decade from 1990 to 2000, the number of bus passengers per year within Shizuoka Prefecture dropped by 67 million.

Pre-planning stage surveys carried out along Route-27 showed that during peak hours buses take 10–15 min to travel 3 km from the Kagoue intersection to the Egawa-cho intersection. Their average speed was around 15 km/h. Growing congestion will slow them further. As a result, the buses were frequently not on their stipulated schedules.

+++ insert FIGURE 3 around here +++

PUBLIC PARTICIPATION IN THE PROJECT AND INCORPORATING THEIR VIEWS AND SUGGESTIONS

Introduction

BRT's key attribute is providing customer-friendly service and the system is designed according to the needs and wants of the customers. This helps BRT to ensure that the public accepts and uses the system. Therefore, obtaining customer input and suggestions is one of the most important parts of BRT planning. Social experiments with different stakeholders pave the path for gathering such valuable planning and design information. Shizuoka authorities also carried out surveys and ran some experiments in the pre-planning stages of the BRT Project.

Pre-Planning Surveys and Social Experiments

During pre-planning, designers tested the effectiveness of the Park & Bus Ride system and a bus-priority lane by collecting opinions of Road-27 from stakeholders. The experiments on the Park & Bus Ride system ran for 10 days from November 11 to November 22, 2002 (on weekdays). From November 18 to November 22, the experiments incorporated the bus-priority lane system. Two temporary parking lots were installed for this experimental period. The bus-priority lane was introduced along a 4-lane section of Road-27. Bus priority was limited to the peak morning-traffic hours (0730 to 0900) and in the direction of peak traffic flow—in the direction of Shizuoka Station.

Park & Bus Ride Experiment

Participants

The experiments ran for 10 days with the participation of 648 passengers (daily average, 65) who used the Park & Bus Ride. Commuters who use their personal vehicles on Road-27 between the Kagoue and Egawa-cho intersections were also invited to take part in the experiment. Prior to the experiment, 806 persons registered for the Park & Bus Ride system, thus the participation rate was 80.4%. Questionnaire surveys were conducted to collect the opinions and views of the users.

During the first five days of the experiment, buses traveling the section between Kagoue and Egawa-cho intersections during the morning peak period took 12–14 min, compared to 10–15 min on normal days—there was no significant difference between the travel times.

Opinions and Views

Questionnaire surveys were conducted to collect the opinions and views of the Park & Bus Ride users. Of the total, 68% answered favorably, giving the system ratings of good (18%) or almost good (50%). Thirty percent supported the formal implementation of a Park & Bus Ride system, while 47% were in favor of it, subject to additional improvements to the system. They suggested changes in the parking location, extending the operating hours of the parking lots to be available from early morning to late night, reducing bus fares, improving the bus-service frequency, and its route structure. Although 68% of the respondents viewed the Park and Bus Ride system positively, only 10% of them said they would use the system, if it was implemented permanently.

Bus-Priority Lane Experiment

Experiment Details

The Experiment of allocating one lane for priority use of buses was carried out for 5 days. Road-27's curb lane between Kagoue and Egawa-cho intersections became bus-priority lanes for the duration of the experiment. General vehicles were allowed to use the priority lane when there was no bus in the lane. No significant violations of priority lane were recorded during the observation period. Some citizens made complaints to the City Office about the experiments while others raised questions, looking for clarification about the project. Most of the complaints focused on the extended travel time of general vehicles due to the restrictions of lane use. The participation rate for the Park & Bus Ride system increased with the introduction of the bus-priority lane experiment. The average daily participation rate was 79.1% during the first five days; it became 81.8% with the addition of the bus-priority lane. This demonstrated some positive feelings towards the bus-priority lane in the minds of personal vehicle users. Questionnaires were conducted to evaluate the response of commuters throughout the 10-day experimental period.

Experimental Outcome

According to a bus-travel time survey carried out on November 6, 2002, from 0730 to 0900, between Kagoue and Egawa-cho intersections, the average bus travel time was within 10 to 15 min on a normal weekday. The introduction of a lane for priority use of buses shortened the bus-travel time by 2–4 min, with a distribution of 8–12 min. Most buses were able to keep to their stipulated schedules.

Among bus passengers, 69% expressed favorable views of the bus-priority lane, rating it as good

(44%) or almost good (25%). Overall, 70% supported formal implementation of the system. Less than 10% of the total sample had negative views of the experiment.

However, the Introduction of a bus lane caused delays in travel time for private automobiles. Their 10-min average travel time on ordinary weekdays over the same section was extended to 12 to 18 min on the first day of the bus-priority lane experiment—an extra delay of 2–8 min. By the last day of the experiment, the delay for automobiles had reduced to 9–14 min—an added delay of 5 min.

An experimental population was selected from among people who live near the street and commute by cars for commuting trips. Among these drivers, 47% did not feel that a bus-priority lane imposed problems for them. Another 50% expressed dissatisfaction regarding the experiment—94% of these commented that the new lane severely affected their trips by extending the travel times.

Kagoue intersection, the starting point of bus-priority lane, had a line of backed-up traffic over 570 m long on the first day of the experiment. By the fourth and fifth days, however, there was no congestion at the site. Zaimoku-cho, the main intersection, saw traffic back up 470 m on the first day. It gradually diminished, reaching only 290 m on the fourth day and 280 m on the fifth day.

Motorcycles were allowed to share the bus priority lane. On the first day of the experiment, however, users were confused about the lane restrictions and most motorcycles used the general traffic lane instead of bus priority lane. By the last day, most of them used the assigned lane.

During the experiment, it was noted that some bicyclists had encroached on the bus lanes. This sometimes led to the bus following the cycles, and slowed bus movement.

From the sample selected from people living near the project, 38% saw it positively, with 17% of the respondents rating the experiment as good and another 21% rating it as almost good. Only 10% rated the experiment as bad or almost bad. Overall, 24% of the respondents supported formal implementation of the system while another 38% were in favor, but wanted to see further improvements in the priority bus lanes and reducing of congestion. Only 15% of respondents opposed the permanent implementation of the system.

SHIZUOKA CITY BUS PROJECT

Features of Shizuoka's BRT

Bus-Priority Lane

After the experiments, the bus-priority lane was installed on October 1, 2004. The curb lane of the 4-lane section of Road No. 27 between Kagoue and Egawa-cho intersections is a bus-priority lane under the Shizuoka BRT Project. The bus priority is limited to the peak morning hours (0730 to 0900) and is effective only in the peak direction (towards Shizuoka Station). It is intended to smooth bus operations between those intersections. The surface of the bus lane is paved with colored asphalt (red) to create psychological awareness over motorists who may block the bus lane. Road signs mounted beside the road as well as messages painted on the bus-lane surface warn drivers of the priority conditions of the lane well in advance. Though the intention of the priority lane is to give preference for buses along the curb lane, it does not restrict the use of the lane for the general traffic. If there are no buses present in the lane, general traffic can use it. This provides the maximum use of the lane while maintaining a bus-friendly environment.

+++ insert FIGURE 4 around here +++

Bus-Priority Signal System

A bus-priority signal system was also installed in October 2004. The signal priority gives preference to system buses, traveling along priority lanes, at intersections. System buses are equipped with radio beacons; each bus has a unique frequency. As the bus approaches an equipped intersection, its radio beacon (emitter) communicates with receivers mounted beside the road. The receiver transmits a signal to the control unit of the nearest downstream direction traffic signal, allowing the traffic signals at intersections to grant the priority for the buses. Signal-priority systems reduce bus travel time by reducing or eliminating the time that the buses spend at red lights.

Stations and Terminals
Before these experiments, major bus stops were provided with shelters. Some major bus stops also offered seating. These stations also provide real-time, next-bus arrival information to passengers via display panels, in addition to standard bus timetables. Every bus stop contains the bus schedules. Several bus stops, especially those located near government housing complexes, offer bicycle parking.

Measuring Performance

Questionnaire and traffic surveys were carried out in two phases: before and after BRT implementation. The initial surveys (Phase-I) were conducted on September 27, 2004, using two different sample categories. The first sample category included people living in areas the project affected. The second sample category included commuters who use the bus between 0700 and 1000. The second group of surveys (Phase-II), conducted on December 14, 2004, included the same respondents as the Phase-I survey.

Measuring Performance through Travel Time
Travel time can be broadly classified into two categories: In-vehicle time and out-of-vehicle time. Access, waiting, transfer, and egress time fall into the second category, while waiting time, in-transit time, and time at stop signals belong to the first. In-vehicle time can be further subdivided into moving and stationary times. In-transit time belongs to the former category.

Access Time The access times for bus passengers before the implementation of BRT were obtained through a bus-passenger questionnaire survey, in Phase-I. As the Shizuoka BRT treatments do not address this component of travel time, it was assumed that the new implementations had no affect on the access time. Therefore, questions on access time were not included in Phase-II of the survey.

Waiting Time Lane- and signal-priority schemes can improve the ability of buses to meet their schedules by minimizing impediments to their movement. This, in turn, reduces the amount of time passengers must wait at bus stops. As the Shizuoka BRT project addressed issues that impede bus transit, data on waiting times, before and after the implementation of BRT solutions, were obtained through the questionnaires.

In Vehicle and Transit Priority lanes and priority signals enhance the speed of the bus. This improved speed shortens bus-travel time, which is the main objective of Shizuoka's BRT project. Therefore, in-bus travel-time surveys were conducted to identify the influence of BRT treatments on bus service.

In Vehicle: Signal Stop Signal-priority systems reduce the amount of time a bus spends stopped at traffic signals. As the Shizuoka BRT project includes a signal-priority scheme, in-bus travel time surveys conducted on September 14 and December 14, 2004 collected data on the before and after effects of the BRT implementation, respectively.

Measuring Performance through Schedule Adherence
Schedule adherence is a comparison of the actual arrival times of a bus at scheduled stops with its schedule time of arrival. Reducing the variations associated with different in-vehicle bus-travel time components (waiting, in transit, signal stop) improves schedule adherence. As the Shizuoka BRT program addresses these components through its bus-priority systems, the before and after results of bus arrival–departure time surveys measured their usefulness. These surveys were conducted on September 14 and December 14, 2004, at major bus stops.

The measure of schedule adherence is the average number of minutes between the actual and scheduled bus arrival times, and its standard deviation. This can be calculated for individual stops, or for the trip as a whole.

Measuring Performance through Ridership

Ridership is an indirect function of all of the BRT components. It reflects how well these components suit customer preferences. Improved travel time, schedule adherence, and other customer-friendly features can make automobile users rethink their travel patterns.

Bus-passenger counting surveys, conducted on September 14 and December 14, 2004, evaluated the effects of Shizuoka BRT solutions on ridership. A bus-passenger survey was carried out to identify new users and the passengers who used buses more frequently after the BRT implementations.

Measuring Performance through Impact on Other Traffic

The BRT projects can have significant effects on other traffic on the BRT route. Priority lanes can increase traffic congestion in the other lanes and on nearby streets. Signal-priority systems may extend the time vehicles on side streets have to wait at traffic signals. These negative effects may influence the behavior of personal automobile users. The severeness of the impact on other traffic can be measured directly by the length of traffic lines and jams. Traffic-count data also indirectly reflects the influence of BRT features. The performance of the Shizuoka BRT project was evaluated using such data, collected through the traffic surveys conducted on October 10, 2002, November 14, 2002, and November 16, 2004.

Measuring Performance through Assessing Public Perception

BRT features should enhance the public's image of bus-transit services. The public perception of the BRT system can be evaluated qualitatively based on the attitudes of both riders and non-riders, using questionnaire surveys. A series of attitude surveys, conducted in Shizuoka City, collected the data using different questionnaires, depending on the individual's modal usage pattern.

Outcomes of Performance Evaluations

Analysis of Congestion Situation

Impact on Line and Jam Lengths at Intersections during Bus-Priority Period: Congestion in General Traffic Lanes The significance of the 10-min interval line lengths and traffic-jam length measurements during the test period, when vehicles were affected by bus priority, were analyzed using one-tailed T Statistics. They were tested based on the null hypothesis (H_0) of no difference against the alternative hypothesis (H_1) of increment/reduction at the 5% level. The tables show the results of analyzed data. In these tables, columns with headings "t stat," "t (crit)," and "$P(T \leq t)$" have the same statistical significance as that of traffic data tables.

+++ insert TABLE 1 and TABLE 2 around here +++

The changes associated with four peak-direction line-length measurements of Road-27 were significant at the 5% level. At 15%, two others become significant. Seven out of nine measurements indicated reducing trends. Though the line lengths at the Naka-cho and Zaimoku-cho intersections increased after the introduction of bus-priority treatment, they did not create adverse effects on the main direction traffic flow of Road-27. The analysis of traffic-jam length associated with peak-direction flow of Zaimoku-cho showed that the new procedure actually eliminated traffic jam conditions that previously prevailed at peak times in that intersection. In addition, the line length at the road's bottleneck—the Shobu interchange—was significantly reduced to around 286 m.

All jam-length measurements except at the Naka-cho intersection indicated reducing trends. At

Naka-cho, there seemed to be some sort of deterioration in traffic flow. On the whole, traffic flow became smoother after implementing the new systems.

+++ insert TABLE 3 around here +++

Impact on Car-Travel Time: Congestion in General Traffic Lanes According to available travel-time data, the mean travel time of general vehicles between Kagoue and Egawa-cho intersections was 10 min and 34 s before the implementation of priority features. It dropped to 7 min and 15 s after the project, thus improving car travel time along the section by more than 30%. This further indicates an easing of congestion in the general traffic lanes.

Reasons Behind the Reductions Associated with Congestion of General Traffic Lanes The data clearly shows an improvement in the traffic conditions of general traffic lanes between the Kagoue and Egawa-cho intersections. This improvement resulted mainly from a reduction in the number of general vehicles using this section of road during the priority period. The reasons for this reduction are (1) changing modal usage patterns from general vehicles to buses, (2) changing departure times (delay or advance in departure times), and (3) changing routes.

Feedback from the questionnaires indicated a 2% net reduction in car usage during the test period. This represents 0.5% of the total sample population and represents the net modal shift, which took place because of priority treatments.

Out of 111 valid responses, 15% stated that they advanced their departure time while another 2% delayed it. Altogether, 17% of the respondents made changes in their departure times, contributing to the reduction in the number of vehicles in the general traffic lane during peak hours.

Out of 111 valid responses, 11% stated that they used only a part of the priority road section after implementing the changes. Another 2% said that they diverted from the route before reaching the priority section; another 4% used alternate routes entirely, instead of using Route No. 27. The bus-priority treatments caused a 6% reduction in general traffic users in the priority areas during peak hours.

Impact on Bus-Travel Times Total bus travel times were assessed with bus-stop surveys as well as by bus-travel time surveys. The effective sample size of bus stop surveys is high, making it more reliable for estimating of the total travel times. These surveys covered details at the vicinity of bus stops. Other travel-time parameters, such as total waiting times, time at signal stops, and total stopping times were assessed through bus-travel time surveys.

The significance of the bus-travel time data within the test period was analyzed..

+++ insert TABLE 4 around here +++

The reduction associated with total bus-travel time within the bus-priority section of the Abe and Miwa lines together was significant at a 15% level, and the Miwa line alone was not significant at that level. However, it also showed signs of reducing.

Impact on Schedule Adherence The significance of bus-schedule adherence during the period that vehicles were affected by bus priority were analysed using one-tailed T statistics.

Schedule adherences within the priority section were significant at the 5% level for both Abe and Miwa lines. The improvements were around 17% and 58% for the Abe and Miwa lines, respectively. Schedule adherence of the Inomiya line was not significant even at a 15% level. Buses from this line enter the bus priority section at its last segment. Therefore, the influence of bus priority treatments on the Inomiya line was negligible.

+++ insert TABLE 5 around here +++

Impact of Priority Treatments in Making Modal Shifts

Changing of Modal Usage Pattern The analysis showed a 14% net reduction in the uses of bicycles, and signs of an increasing trend toward pedestrian travel. Further, the number of bus users increased by 7% while car users decreased by 2%. Four respondents who had used cars became bus riders after the project. However, three respondents shifted from bus to car. Therefore, the net change from car to bus was one person, around 0.5% of the sample population. The increase in bus users was 2% and the reduction in car use was around 1%. Although percentagewise the figures are small, in a real situation, the project may a considerable affect on traffic conditions. Road-27 showed signs of easing traffic congestion and smoother traffic flow from the bus-priority treatments. The trends associated with modal shifting contributed to making that positive environment.

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CONCLUSION

Effectiveness of Priority Treatments as a Countermeasure for Traffic Congestion

All vehicles, excluding buses and two-wheeled vehicles, which used the peak direction lanes of Road-27, showed a reduction in travel-time trends at all nine major intersections. The reductions associated with two of the nine intersections were significant at the 5% level. Eight of nine peak-direction traffic flows at surrounding intersections of Road-27 showed growth, indicating that drivers were using alternate routes.

The traffic line lengths along the peak-direction legs of Road-27 indicated reducing traffic trends. Seven out of nine major intersections showed negative growth, with the reduction associated with three of them significant at the 5% level. Mean car-travel time between Kagoue and Egawa-cho intersections was reduced by 30%.

The mean total bus-travel time on the Abe and Miwa Otani lines within the priority section dropped by 6.2%, and was significant at a 10% level. Schedule adherence of Abe and Miwa Otani line buses within the section improved by 17% and 58%, respectively.

These results support the idea that there have been improvements in traffic flow on the test route. Therefore, it can be concluded that priority treatments were successful in minimizing traffic congestion.

To summarize, it can be concluded that bus-priority treatments were effective as a countermeasure for traffic congestion.

Effectiveness of Priority Treatments as a Countermeasure for Modal Shifting of Transport Options

Feedback from the questionnaires indicated a net 2% modal shift took place from other modes to bus transit after the implementation of bus-priority systems. This was one positive impact of priority treatments. The feedback further indicated a net 0.5% modal shift took place from car to other modes. This was another positive impact of the bus-priority systems. According to the questionnaires, there was a net 2% reduction in the use of cars and a net 7% increase in the use of buses.

Thus, it can be concluded that the bus-priority systems were an effective countermeasure for modal shifting.

Recommendations

The total bus travel time of the Abe line within the section prior to the starting point of the bus priority lane increased by 16.7% and the reduction was significant at a 10% level. Deviations from scheduled arrival and departure times of the Abe line buses within this section increased by 44%. Thus, there was a clear deterioration of bus service within this section, and it is necessary to improve bus travel within that section by adopting some type of bus-priority treatments.

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List of Tables and Figures

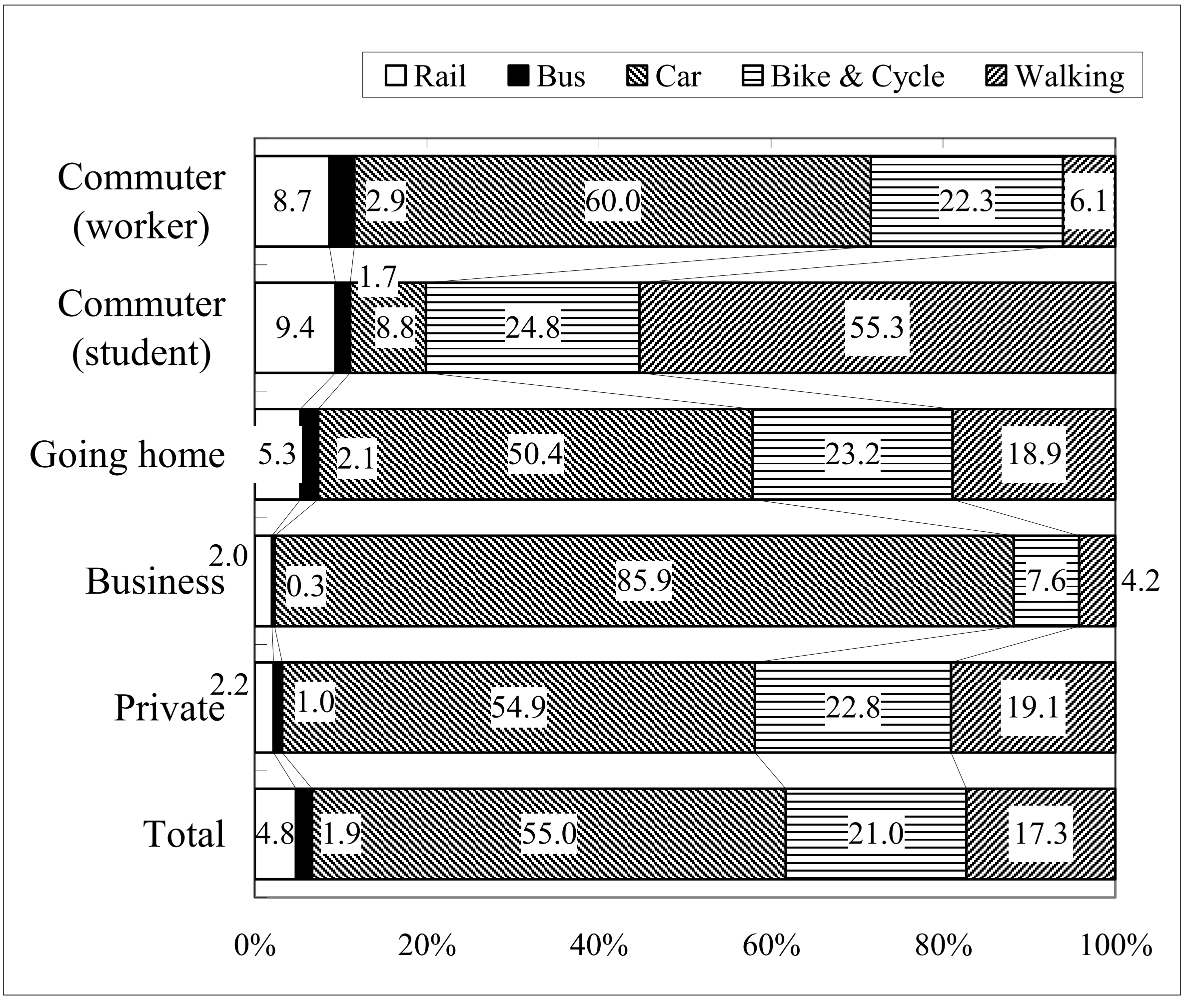

FIGURE 1 Modal-Share Distribution (by passengers carried) Based on Trip Purpose (Shizuoka Prefecture, 2001).

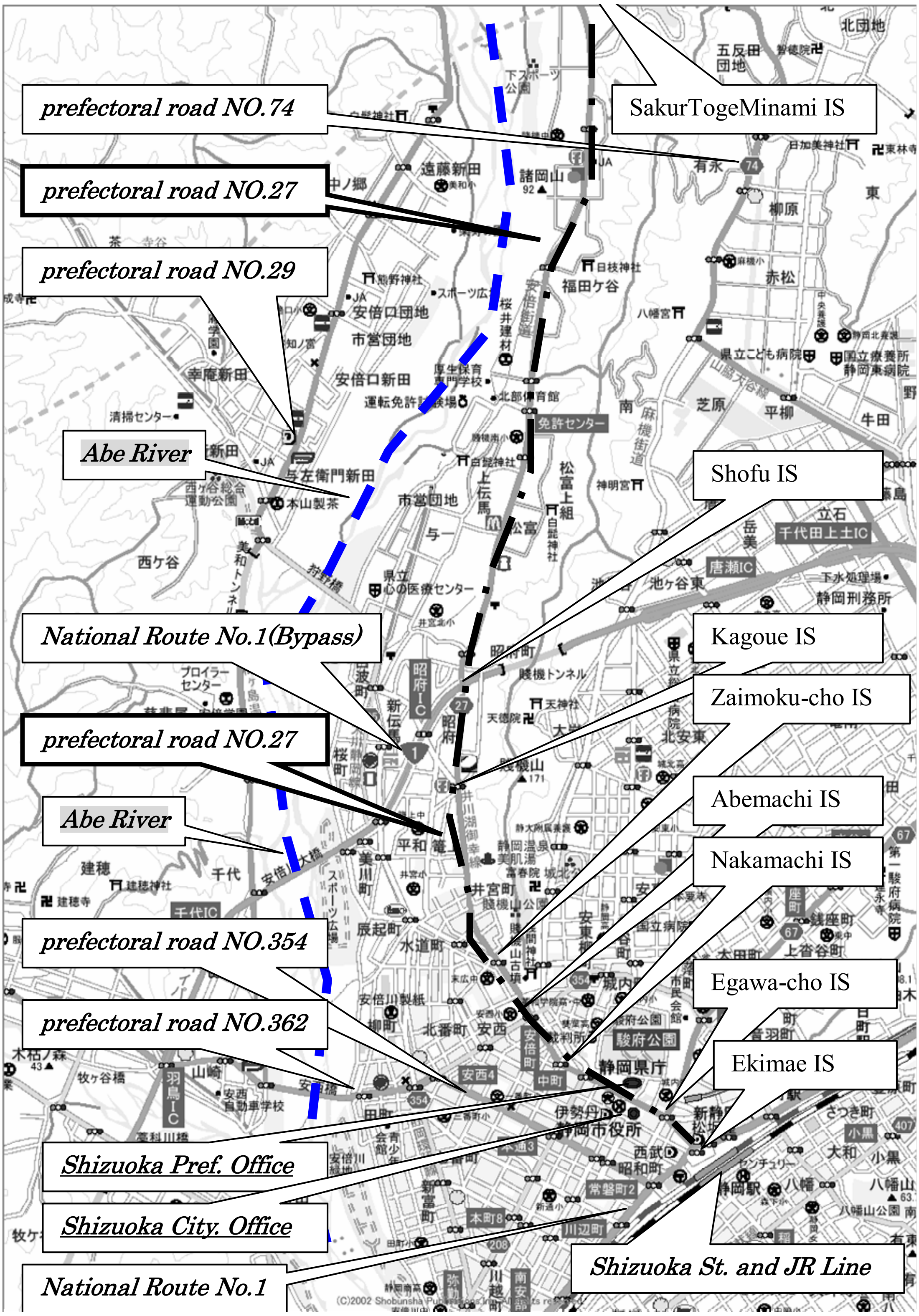

FIGURE 2 Map of Shizuoka City (map of area surrounding prefectoral Road No. 27).

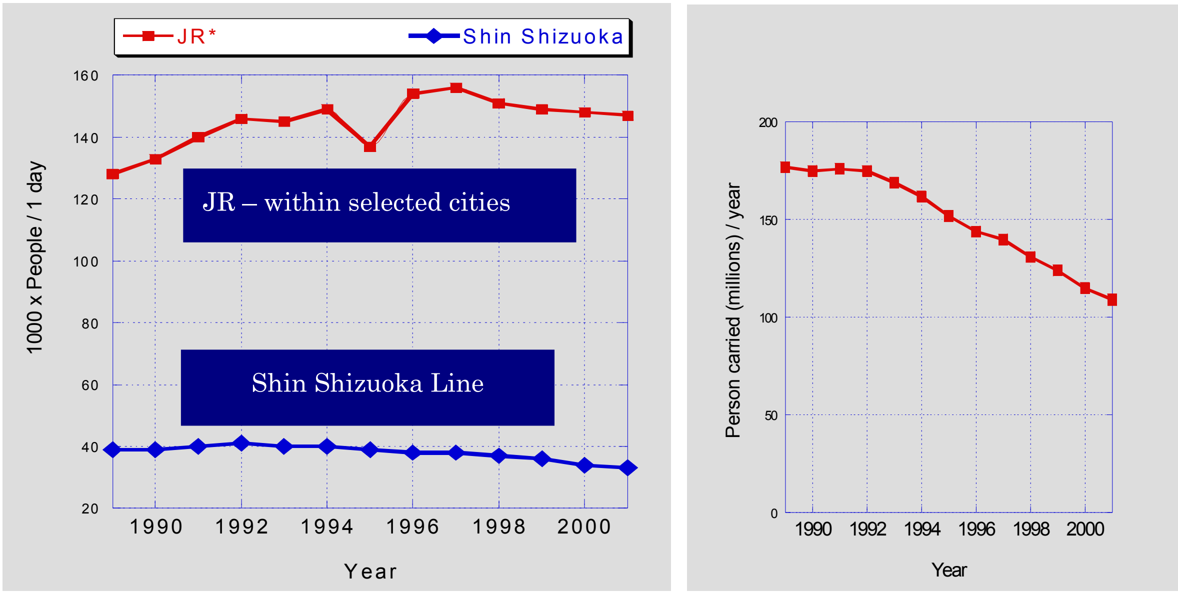

FIGURE 3 Trends in Ridership by the JR and Shin Shizuoka Lines(left) and Buses(right).

FIGURE 4 Bus-Priority Lane (left) ,Bus in the Priority Lane (centre) and Bus Stops with Shelters (right).

TABLE 1 Impact on Line Lengths in General Traffic Lanes of Road-27 (at Major Intersections)

Name of Intersection	Before		After		t Test Results		n	
	Mean	Var.	Mean	Var.	t (Stat)	P(T ≤ t)	T (crit)	
Egawa-cho IS	*206.67*	*1944*	*161.11*	*1811*	*2.230*	*0.020*	*1.746*	*9*
Naka-cho IS	*163.33*	*2956*	*166.67*	*4525*	*–0.116*	*0.455*	*1.753*	*9*
Abe-cho IS	*99.44*	*334*	*95.56*	*827.8*	*0.342*	*0.369*	*1.761*	*9*
Abe-cho Kita IS	*224.44*	*4378*	*141.11*	*1186*	*3.352*	*0.003*	*1.782*	*9*
Zaimoku-cho IS	*90.00*	*475*	*108.89*	*311.1*	*–2.021*	*0.031*	*1.753*	*9*
Inomiya-cho IS	*12.78*	*50.69*	*10.00*	*0*	*1.170*	*0.138*	*1.860*	*9*
Kagoue IS	*49.44*	*659*	*35.56*	*177.8*	*1.440*	*0.088*	*1.782*	*9*
Shobu IS	*433.89*	*58686*	*147.78*	*2069*	*3.482*	*0.003*	*1.833*	*9*
Sakura Toge Minami IS	*385.56*	*4453*	*338.89*	*78761*	*0.485*	*0.320*	*1.833*	*9*

Note: n, number of 10-min interval maximum line-length observations; units of mean, meters

TABLE 2 Summary of Impact on Traffic-Line Lengths along Road No. 27

Name	Significance		Trend	Change		Length
	5%	15%		Num	%	
Egawa-cho IS	O	O	N	–45.6	–22.0	Major
Naka-cho IS	X	X	P	3.3	2.0	Major
Abe-cho IS	X	X	N	–3.9	–3.9	Major
Abe-cho Kita IS	O	O	N	–83.3	–37.1	Major
Zaimoku-cho IS	O	O	P	18.9	21.0	Major
Inomiya-cho IS	X	O	N	–2.8	–21.7	Minor
Kagoue IS	X	O	N	–13.9	–28.1	Major
Shobu IS	O	O	N	–286.1	–65.9	Major
Sakura Toge Minami IS	X	X	N	–46.7	–12.1	Major

Note: % change of line lengths after the improvements
O: significant; X: not significant; N: reduction in length; P: increase in length
Minor length: length < 50 m
Major length: length ≥ 50 m

TABLE 3 Impacts on Jam Lengths in General Traffic Lanes of Route-27 (at Major Intersections)

Name	Before		After		t Test Results			n
	Mean	Var.	Mean	Var.	t (Stat)	P(T ≤ t)	t (crit)	
Egawa-cho IS	210.0	8756.3	117.8	9044.4	2.074	0.027	1.746	9
Naka-cho IS	31.1	8711.1	78.9	15011	-0.931	0.183	1.753	9
Abe-cho IS	0.0	0.0	0.0	0.0	-	-	-	9
Abe-cho Kita IS	158.3	14350	22.2	4444.4	2.979	0.005	1.771	9
Zaimoku-cho IS	14.4	1877.8	0.0	0.0	1.000	0.173	1.860	9
Inomiya-cho IS	0.0	0	0.0	0.0	-	-	-	9
Kagoue IS	0.0	0	0.0	0.0	-	-	-	9
Shobu IC	98.9	39911	16.7	2500.0	1.198	0.131	1.833	9

TABLE 4 Total Bus-Travel Times within the Bus-Priority Section (from Bus-Stop Surveys)

Trip Description	Before		After		t Test Results		
	Mean	**n**	**Mean**	**n**	**t (Stat)**	**P (T ≤ t)**	**t (crit)**
Abe & Miwa lines (Kenchou-Sougozimashimae)	*10:43*	*22*	*10:03*	*20*	*1.495*	*0.07152*	*1.685*
Abe Line (Kagoue - Kenchou-Sougozimashimae)	*10:39*	*12*	*09:40*	*10*	*1.549*	*0.06856*	*1.725*
Miwa Line (Kagoue - Kenchou-Sougozimashimae)	*10:49*	*10*	*10:26*	*10*	*0.6*	*0.27821*	*1.74*

Note: n, number of bus trips; unit of mean, minutes:seconds per bus trip

TABLE 5 Bus Schedule Adherences within the Bus-Priority Section

Trip Description	Before		After		t Test Results		
	Mean	**n**	**Mean**	**n**	**t (Stat)**	**P(T ≤ t)**	**t (crit)**
Abe Line (Kagoue Intersection - Shin Shizuoka)	*03:50*	*117*	*03:10*	*103*	*2.029*	*0.022*	*1.652*
Miwa Line (Kagoue Intersection - Shizuoka-eki mae)	*04:27*	*139*	*01:53*	*129*	*7.277*	*0.000*	*1.651*
Inomiya Line	*02:38*	*28*	*02:17*	*32*	*0.704*	*0.242*	*1.675*

Note: n, number of bus trips; unit of mean, minutes:seconds per bus trip

TABLE 6 Changes Associated with Modal Usage Patterns after Implementation

Mode		After mode					
		Bus	**Car**	**Motorcycle**	**Bicycle**	**Walk**	**Total**
Before Mode	**Bus**	52	3	0	0	1	56
	Car	4	91	1	1	0	97
	Motorcycle	0	0	18	1	0	19
	Bicycle	4	1	0	16	0	21
	Walk	0	0	0	0	2	2
	Total	60	95	19	18	3	195