

Evaluating Bus Rapid Transit System in Nagoya City

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ABSTRACT

This paper empirically explores the impacts and discusses the advantages of the two BRT systems "Key Route Bus System", operating on exclusive median bus lane system and "Guideway Bus System", operated on elevated mechanical track guidance system. These systems have been introduced (Key Route Bus: 1985, Guideway Bus 2001) in Nagoya which is the third largest city in Japan.

The analysis for the Key Route Bus System suggests that: 1) Median bus lane and longer distances between bus stops improve the operational speed and punctuality, and therefore this higher service enables to minimize the decrease of passengers compared to the other bus routes; 2) It increases the road capacity and decreases the environmental load; 3) It does not have any notable impacts on urban development. For the Guideway Bus System the three important conclusions are: 1) High operational speed and punctuality is attained through elevated alignment which is completely elevated from the car traffic and signalizations on the roads; 2) Rate of increase in passenger demand is higher than that of population because of higher level of service; 3) Current legislation system in Japan requires complex operation system and elevated track lane for Guideway Bus System and this makes the operational cost higher compared to the other applications in other countries.

1. INTRODUCTION

BRT (Bus Rapid Transit) systems have been increasingly gaining attention in developing countries as the systems that provide high quality public transport services operating at higher speeds on the exclusive lanes. Therefore BRT systems are often regarded as alternative modes to railways as they utilize the advantages of lower construction costs and more flexible in route determination compared to the railway systems.

Increasing number of BRT applications has drawn the attention of many researchers and has produced considerable number of researches on the real cases of BRT developments. Levinson et al. (1) identify the requirements as BRT systems by reviewing many cases in North and South America, UK and Australia. And they provide a guideline for introducing BRT systems (2). Wright (3) and FTA (4) (Federal Transit Administration) also provide guidelines.

In many cities of the developing countries, highway network developed earlier than the public transport network. This contributed to the rapid expansion of motorization and as well as urban sprawl because in many cases land use regulation has been rather poor to manage motorization and urban dispersion. Therefore, Satiennam et al. (5) suggest that applying these above guidelines directly is difficult.

In Japan there are some cases to improve bus running condition. In Nagoya city, two BRT systems have been developed through arterial roads. Nagoya city is similar to metropolitans of developing countries with a point of poor land use regulation.

This paper not only provides case study results to the literature on BRT systems but also constitutes a document for the dissemination of know-how and experience to numerous other cities for encouraging them to include BRT systems in their transport development plans.

2. BRT SYSTEMS IN NAGOYA

2.1 Outline of Nagoya City

Nagoya metropolitan region is the third largest populated urban region in Japan. The total population of the city in 2006 was 2.22 million in an area of 326 km². The population was almost the same as that of Paris (2.14 million in 2004), but the urban area is three times larger (Paris area is 105km²) and therefore population density is lower in Nagoya.

The main characteristic of transport in Nagoya is the excess provision of streets which were rapidly improved after the Second World War. The total road surface in the city center is approximately 40% of the total central area, making Nagoya the "the city of wide roads" in Japan. As one result of low population density and extensive road network with high capacity, the car traffic was induced and the share of the trips made by private automobiles is 70% today and this is higher than those for Tokyo or Osaka, other two biggest urban settlements in Japan.

The public transport service in the city is provided by suburban railways, subways and busses (including BRT systems). The total length of subway is 89.1 km and buses are operating on approximately 700 km length of the bus network.

Currently there are two BRT systems operating in Nagoya city (See **FIGURE-1**). The first BRT system is called "Key Route Bus System" and is the first BRT system that operates on exclusive median bus lane in Japan; the second BRT system is called "Guideway Bus System". **FIGURE-2** shows the route map of these two BRT systems.

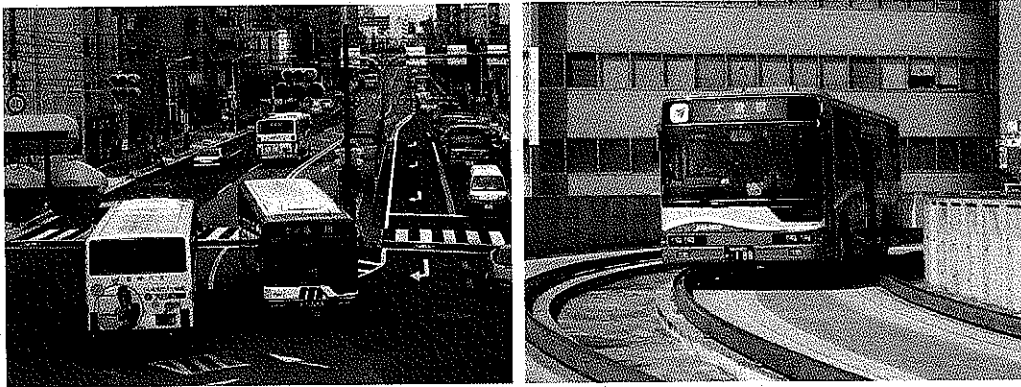


FIGURE-1 Nagoya BRT systems (Left: Key Route Bus, Right: Guideway Bus)

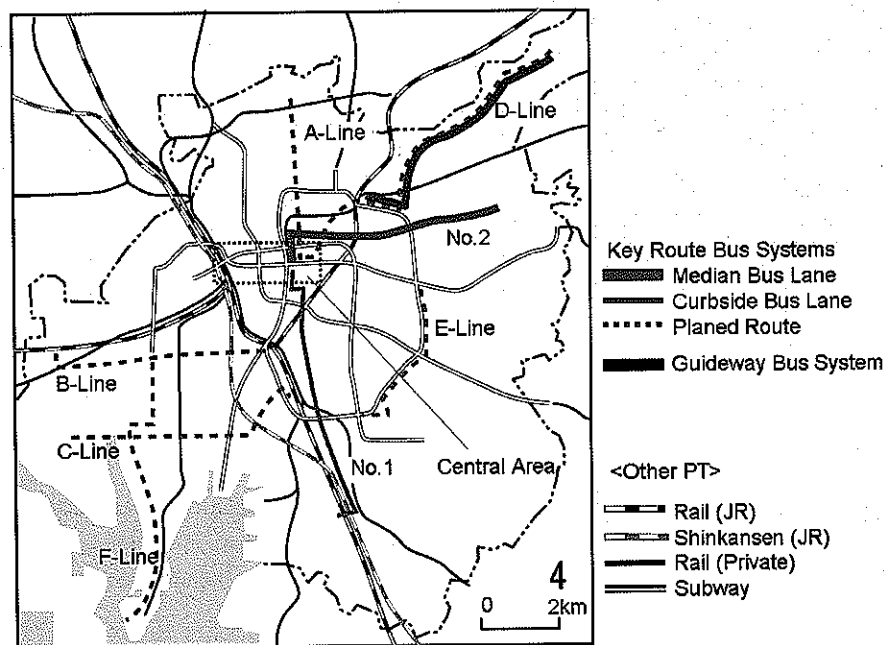


FIGURE-2 Routes of Nagoya BRT Systems

2.2 Key Route Bus System

Key Route Bus System was first proposed in 1979 by a planning committee established by many experts and researchers as one very important policy for the improvement of transport system in the city. The speed and the punctuality of bus systems were drastically worsening in the late 1970s due to rapid motorization. Therefore separate bus lanes might provide effective solution to the increase of level of services of the bus systems

The characteristics of Key Route Bus System were specified by this committee as below:

- 1) exclusive bus lanes in the middle of the roads as a similar system to tramways
- 2) higher operational speed (25km/h) by introducing bus prior signal system and expanding the bus stop intervals (800-1000m)
- 3) introduction of higher capacity buses with more doors
- 4) decreasing the physical transfer difficulties and providing better fee system to encourage transfers between the modes

This system was planned as an alternative system to the planned subways and also as major transit systems to the areas without subway systems. Planned routes are given in FIGURE-2.

In 1982, the first section of the Key Route Bus No. 1 named as "Toko Line" was opened. Totally 15 bus

stops were selected from existing 24 stops for Toko Line. However, the central part of this street had already been occupied by pillars of the elevated expressway and therefore the curbside bus lane was designed. Therefore, Toko Line was far from the BRT system specified by the committee. Although the system was not a good system as was planned, the operational speed of the bus increased from 13.0km/hr to 17.0km/hr.

Three years after the first section Key Route Bus second section was opened. This route was named as Shin-Dekimachi Line was the first and the only application of exclusive median bus lane in Japan. The total construction cost is approximately 2.5 million \$ per kilometer, which is only one percent of the cost for subway. After the introduction of the median bus lanes, the operational speed of the bus during daytime increased from 14.6 km/hr to 19.9 km/hr (approximately 37%) This speed is the same as BRT system in Curitiba, Brazil. In addition, the system allowed higher frequency of 2-minute headways in the morning peak hours. **TABLE-1** gives service level of Shin-Dekimachi Line and **FIGURE-3** shows its route. The intervals of bus stops are approximately 600m, twice as much as the ordinary bus stops in the city.

In Shin-Dekimachi Line, longer distances between bus stops to increase the capacity were attained but bus prior signals, higher capacity vehicles and better transfer between the modes remained unimproved. And Special colored buses were introduced. Recently, low floor buses are installed.

TABLE-1 Service level indices of Key Route Bus (No.2)

Operational Speed	Average time for one trip	Peak Volume of Buses
19km/h	30min	33 /h

Routes

- Sakae – Hikiyama
- Nagoya Central Station – Hikarigaoka / Idaka Shako
(These two routes are operated by Transportation Bureau of City of Nagoya)
- Nagoya Central Station – Shiken-ya etc.(East Area from Hikiyama)
(This route is operated by Meitetsu Bus Co.,Ltd)

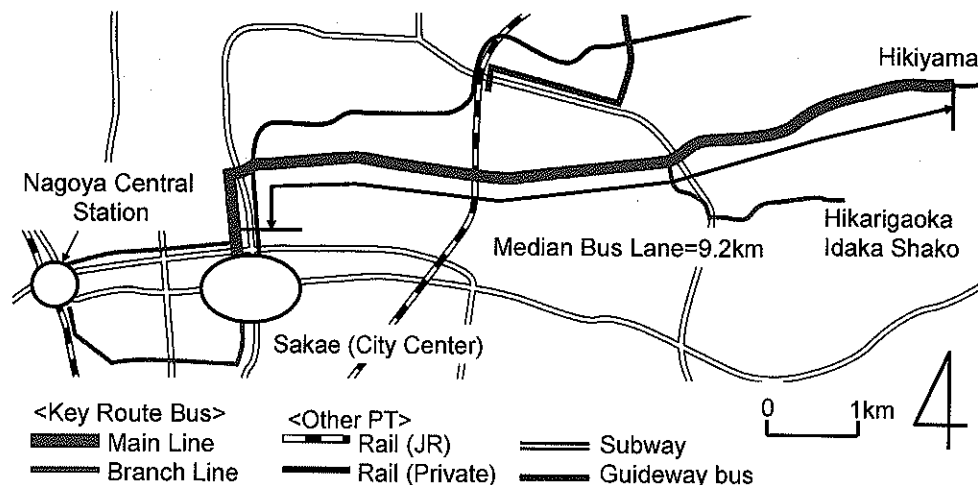


FIGURE-3 Route of Shin-Dekimachi Line (Key Route Bus No.2)

Key Route Bus System has been one important transit system in Nagoya. However new routes have not been added and for the planned D, E and F Key route bus lines shown in **FIGURE-2** other alternative modes were selected. Guideway Bus for D-line; subway for E-line; and railway transformed freight line for F line were provided. The major reason why Key Route Bus System has not been further implemented is mainly the road traffic act in Japan. For the construction of the Shin-Dekimachi Line there have been many required

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case-specific treatments, which have not been justified by the existing regulations not allowing the buses to run in the central lanes. Therefore, special to Shin-Dekimachi Line, it has been deregulated to allow the buses to be registered as "Key Route Buses" using such exclusive lanes.

2.3 Guideway Bus System

Guideway Bus System uses the curb guided bus technology. Curb guided buses have been introduced in Essen, Germany and Adelaide, Australia, Leeds, UK etc(6). Guideway Bus System applies mechanical track guidance by derivation of drive guiding wheel attached to vehicles and guiding rail attached on the elevated track. Therefore such bus systems utilize the advantages of:

- 1) higher speed on completely segregated lanes where other vehicles are not allowed
- 2) vehicles are able to run both on elevated tracks ground level roads as well using special interchanges
- 3) width of track can be narrow, therefore construction cost (approximately 50 million \$ per kilometer) is lower than that of construction the highways
- 4) higher capacity compared to Key Route Bus System

TABLE-2 gives service level performances and FIGURE-3 shows the route of Guideway Bus System. It connects the north east area of Nagoya city (Shidami, Moriyama-ward) and Ozone station where subway and suburban railway lines concentrate to meet the increasing transport demand of the increasing population as a result of the land readjustment projects promoting development in this area.

TABLE-2 Service level characteristics of Guideway Bus (7)

Routes	Operational Speed	Average time for one trip	Frequency of Buses on elevated track	Frequency of Buses on ground level roads
4	30km/h(Elevated Track) 18km/h(Running on ground)	13 min(Elevated Track) 28 min (Ozone to Naka-Shidami)	3-5 min(Peak hour) 10 min(Daytime)	10 min (Obata Ryokuchi to Naka-shidami)

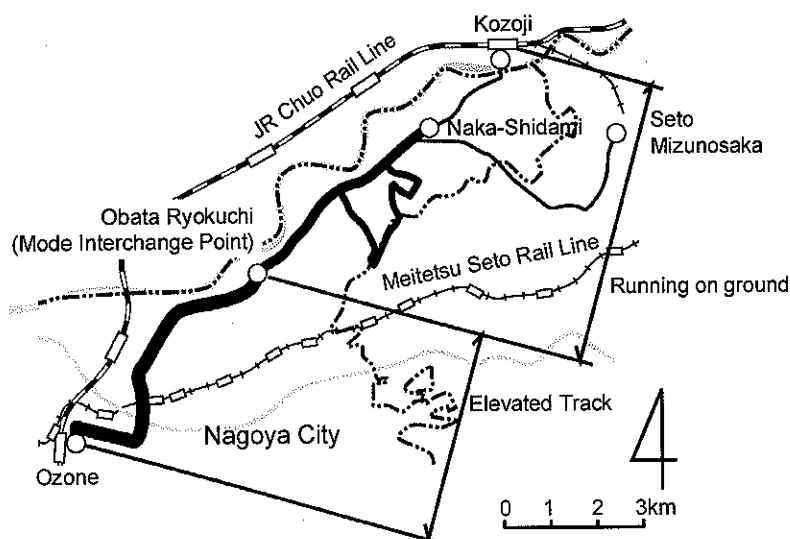


FIGURE-3 Route of Nagoya Guideway Bus Shidami Line

The Guideway Bus System named as “Nagoya Guideway Bus Shidami Line” or “Yutorito-Line (official nickname, combination of the Yutori (Relaxed or comfortable in Japanese) and street)”.

Guideway Bus System consists of two main parts of :

- 1) elevated track and segregated lane (6.5km, Ozone station to Obata Ryokuchi station) with nine stations
- 2) ground level roads and mixed traffic with primary general cars (Obata Ryokuchi station to north east area)

In transport development plans this route was selected as a candidate route for new Key Route Buses. However, the road width in the built-up area is too narrow (four-lane) to develop Key Route Buses and therefore Guideway Bus System running on elevated track in the built-up area was preferred instead. On the other hand, since car traffic in developing area was not so heavy, elevated track was not constructed there.

3. BRT SYSTEMS

FTA (Federal Transit Administration) organizes the main elements of BRT systems in to three groups as illustrated by FIGURE-4 (4). Main elements of Key Route Bus System and Guideway Bus System have already been introduced in section 2. In this section other main elements of “Performance” and “System Benefits” are discussed.

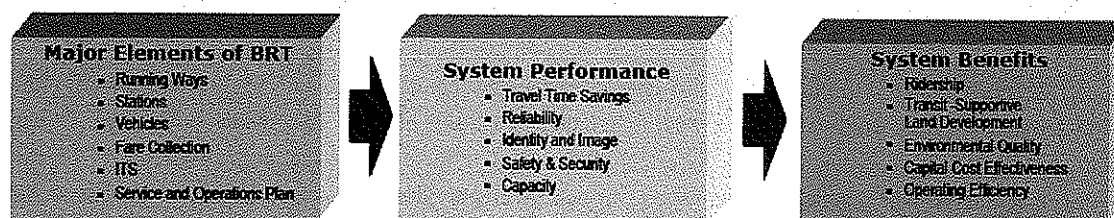


FIGURE-4 Elements of BRT system

3.1 Key Route Bus System

3.1.1 System Performance

Travel Time Savings and Reliability As mentioned earlier, the operational speed was improved by 37% (up to 19.9 km/h) and has been stable around 19 km/h since the construction of the system. This average speed is 1.5 times higher than that of ordinary buses operating in Nagoya city. FIGURE-5 shows the improved operation performance through attained higher speed by Key Route Bus compared to the ordinary buses, using the results of the speed survey conducted by the Nagoya City Office(8). Running time reduced by 32% and stopping time were well shortened by 46% through decreasing the number of bus stops and operating on median bus lane that diminished the effects of road parking and turning cars. However, stopping time at signals were less improved and only decreased by 18%.

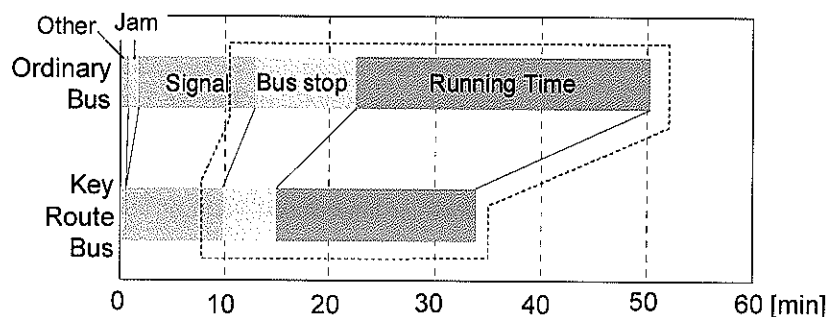


FIGURE-5 Speed-improvement and punctuality effects

The share of stopping time at the signals over the total trip time is 27% and therefore it would not be wrong to say that if the Key Route Bus had not been stopping at signals, the operational speed could have been improved from 19 km/hr to 26 km/hr. One solution to such improvement would be the introduction of bus priority signals. But it has not yet been implemented because the headway time of Key Route Bus No.2 is shorter than the signal cycle in peak hours. Therefore, installing bus priority signal is not effective in the peak hours. Instead, line control signal system considering the bus operational speed has been installed. However in off-peak hours, bus priority signal would be effective to increase the operational speed.

Capacity The maximum capacity of Key Route Bus System which uses the ordinary buses is approximately 50 vehicles/hr and 4,000 number of hourly passengers. Currently, on Shin-Dekimachi Line 33 vehicles are operated in the peak hour. However, frequency has been gradually decreasing because of the decreasing of passenger demand.

3.1.2 System Benefits

Ridership Key Route Bus System characterized by higher operational speed and punctuality offers convenience over ordinary buses and is expected to attract more passengers. The survey shows a shift to Key Route Bus only by 3% of total car trip demand.

FIGURE-6 shows the changes in passenger demand for the Key Route Bus No.2 taking the demand in 1988 as 100. The number of passengers for the Key Route Bus decreased to 85.6 in 2003 but this was a smaller decline compared to that of total bus passenger demand that decreased to 69.8. Decrease in the number of passengers for Key Route Bus No.1 was higher than No.2 and became 79.4 in the same term. It can be concluded that the median bus lane has any effect on maintaining the decrease rate in bus passengers. Therefore we reach the important conclusion that better service level provided by exclusive median lane may better maintain the bus user demand compared to the other two types of ordinary and exclusive curbside lane bus services in Nagoya.

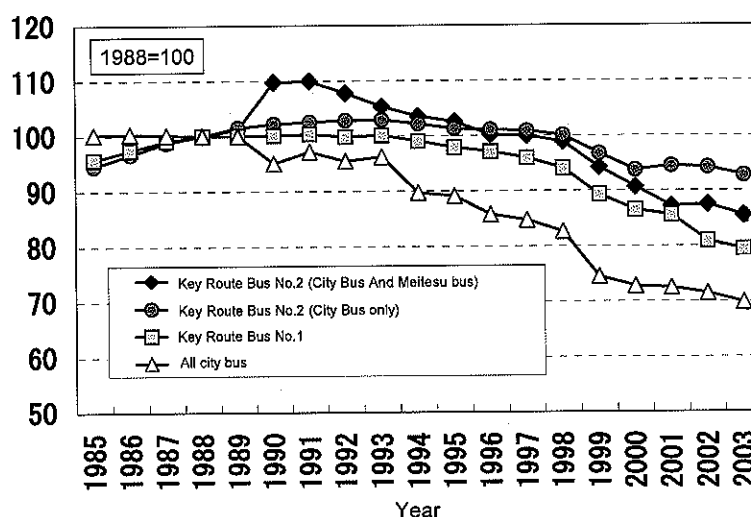


FIGURE-6 Changes in passenger demand since Key Route Bus No.2 has been operated

Transit-Supportive Land Development As consequence of the generally accepted interaction between the transport and the land use, it is likely to prove an interrelation between housing, commercial location patterns and the Key Route Bus line with potential to attract more facilities based on the principle of Transit Oriented Development along its corridor. However, almost all the areas where the Key Route Bus was introduced is a built up area and the measure of consolidating the land use along corridor is not taken. TABLE-3

presents the population changes since the 1980 separately for the areas within 500m far and the area 500 to 1,000m far from each bus stop, and the other accessible along the line. It should be noted that the area has already been developed before introducing median bus lane, and recently facing population decline that is common to many cities and is a recent phenomena in Japan. However the Key Route Bus of Nagoya hardly puts any evidence of transit oriented development along its line or nearby the bus stations. The population decline rate within 500 m zones was less than that within the zones 500m to 1000 m but higher than the other zones.

TABLE-3 Population, changes along the Key Route Bus

Population	1980	1990	2000
(1) Within 500m zone	81,930	84,073	81,108
(2) 500-1000m zone	111,936	109,774	104,064
(3) Others	169,084	186,172	184,259
Change rate of population	1980-1990		1990-2000
(1)500m zone	+2.62%		-3.53%
(2)500-1000m zone	-1.93%		-5.20%
(3)Others	+10.1%		-1.03%

Decreasing in CO₂ Emission Since the fuel consumption and environmental load from the buses can be improved by increased average operational speed, we estimated such effects of the median bus lane by employing the fuel consumption model suggested by Oshiro et al. (9). Implementation of a curbside bus lane reduces energy consumption by 8% and a median bus lane reduces it by 13% comparing with ordinary buses (see TABLE-4). Additionally, an actual 3% shift from car trips to buses, mentioned earlier, also contributed to the reduction of environmental load by the amount of 370 t-CO₂/year. Therefore we estimated that the median bus lane totally reduces the carbon dioxide emission by 607t/year.

TABLE-4 Reduction of the environmental load

Estimated Mode Value	Operational speed [km/hr]	Fuel consumption [km/L]	CO ₂ emission [ton-CO ₂ /year]	NO ₂ emission [ton-NO ₂ /year]
Median bus lane	19	3.58	1,520	11.2
Curbside bus lane	16	3.35	1,620	12.0
Ordinary bus	13	3.10	1,750	13.0

Operating Efficiency Both of the two Key Route Bus lines are operated by Transportation Bureau of City of Nagoya has started to earn profit recently while almost all bus lines are encountering financial problems of deficit. This is mainly because of the passenger demand and higher operational speed.

3.2 Guideway Bus System

3.2.1 System Performance

Travel Time Savings and Reliability Elevated track is completely separated from road. Therefore buses are able to run at high operational speed of 30km/hr. This is almost a similar speed to that of subways. Therefore running time substantially decreased from 32 min to 13min between Ozone station to Obata Ryokuchi station where the distance is 6.5 km. Besides, punctuality also increased as another advantage of this elevated track.

But to minimize the delays of the whole system it is important to maintain the punctuality of Guideway Bus attained on the elevated track also on the roads where the system becomes an ordinary bus operation. For this reason two important area surveys were conducted for investigating the punctuality of the system; one is just in April 2001, just after Guideway Bus opening, and the other is in April 2006, five years after from its opening.

FIGURE-7 shows the result of these surveys. In April 2001, buses were able to run at high punctuality arriving on times determined by the time-tables even in peak hours. Results of the second survey showed that in 2006, buses were delaying at selected investigation stations, but these delay times were then recovered in peak hours before arriving at Obata Ryokuchi station where elevated track section starts.

This was mainly because of setting bus lanes in peak hours. Therefore, we conclude that the punctuality of Guideway Bus at the ground sections is also maintained. But for off-peak hours, delay time was not recovered in 2006. The difference between the results of April 2001 and April 2006 that led to this result is existence of intraregional transport demand to the regional center considerably observed in April 2006, which was few in April 2001. Fare collection of Guideway Bus System was also changed to in-vehicle collection system because this was also considered as one reason for the delays.

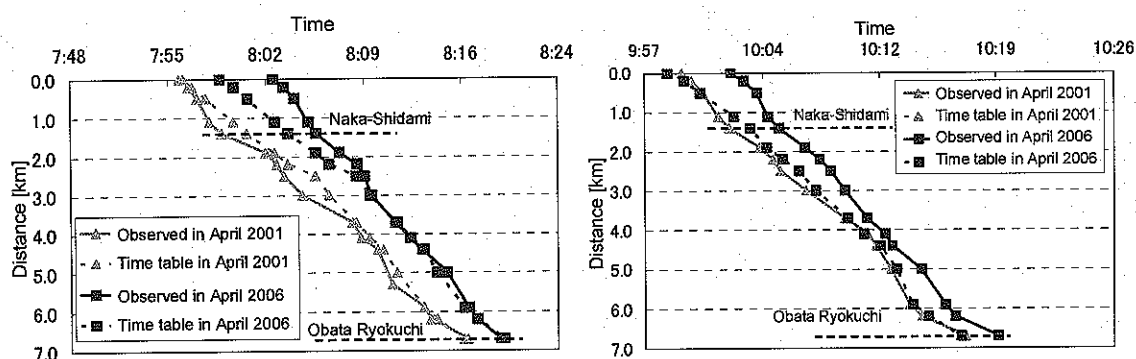


FIGURE-7 Result of investigation for punctuality (Left: peak hour, Right: day time)

Capacity The maximum capacity of Guideway Bus System is approximately 10,000 passengers per hour per direction. Since the passenger demand of Guideway Bus in weekdays is approximately 10,000/day, capacity is enough to meet this demand. However passenger demand increases at some stations on elevated track are observed in peak hour therefore it is required to introduce high capacity buses as they are crowded at these sections in peak hours. But currently this is difficult to renew fleet and operate such new vehicles because of the regulation in Japan (Road traffic and barrier-free regulation).

3.2.2 System Benefits

Ridership FIGURE-8 shows the trend of number of passengers for Nagoya Guideway Bus Shidami-Line. It shows that number of passengers is continuously continuing increasing. Number of passengers raised by 70% between 2001 and 2006. This is more than the increase rate of population (4% at whole Moriyama ward, 40% at whole developing area). Therefore, we conclude that increase in passenger demand is attributable to high service level attracting more passengers.

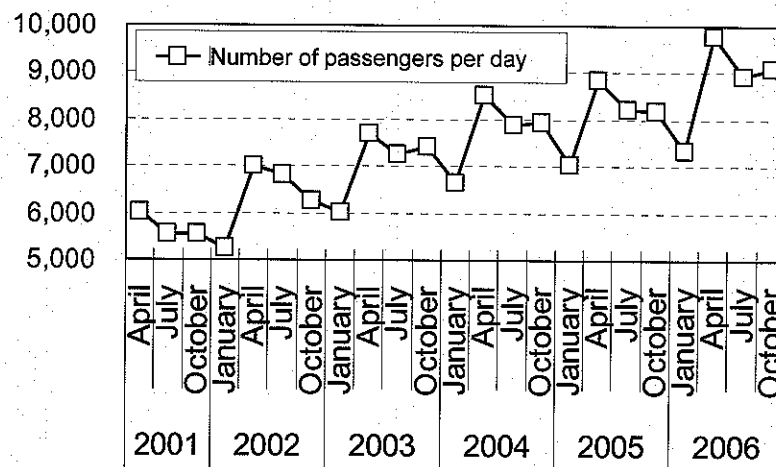


FIGURE-8 Number of passengers of Shidami Line

Transit-Supportive Land Development FIGURE-9 shows the number of ridership at each bus stop on the ground level section. It is interesting to note that the ridership at these bus stops is although slightly increasing despite the fact that the neighboring population is not growing. Whereas a slight decrease is observed at bus stops where the neighboring area is developing and population is growing. Only at one bus stop the ridership was doubled. This is also because of the sharp fare increase and applied fare system. Currently maximum fare is on only elevated track section is 240yen (2.22\$, from Obata Ryokuchi to Ozone) but fare from this zone to terminal is 420yen (3.88\$). This obviously leads to decrease of demand that the nearby residences do not prefer to use Shidami Line.

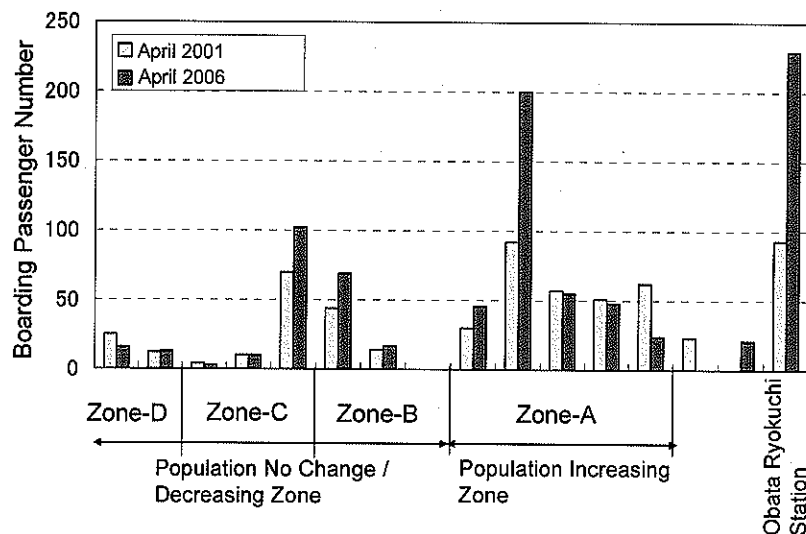


FIGURE-9 Ridership at each bus stop

In the meantime, ridership at Obata Ryokuchi station increased and nearly doubled although the neighboring population increase is slight and there are no attractive facilities around this station. The main reason is that many parking lots for park and ride and bicycle-parking space at Obata Ryokuchi station are provided, and inhabitants living in developing area may use to avoid expensive fare.

Efficiency of Operation Generally, higher operational speed increases the efficiency of operation. This is one of the merits of BRT system. However, Guideway Bus System on the elevated track is treated as "tram", not "bus" under the Japanese legal systems concerning public transport. As a result, running cost of Shidami Line is almost same as railways because of additional cost and it decreases operational efficiency. Nagoya Guideway Bus Co., Ltd., operating elevated track section must pay a part of infrastructure construction cost, and it is suffering from large amount of accumulated deficit despite the increase in passenger demand.

In addition, there are different bodies operating the elevated track section and ground level section. On the ground section, buses are operated by three operators (two private companies provide bus service in this area and transportation bureau of city of Nagoya). For the elevated track section, Nagoya Guideway Bus Co., Ltd. manages three bus operators in running on the ground section operate by the commission from Nagoya Guideway Bus Co., Ltd. This complicated style makes total fare rise.

4. CONCLUSIONS

Implementations of Bus Rapid Transit Systems have been increasing with a variety of applications for vehicles, stations and operation systems. The main concern of this paper is to evaluate the performance and benefits of BRT systems in Nagoya city, the third biggest settlement in Japan

For Key Route Bus, major results can be summarized as below:

- The implementation of median bus lane and the increase of the distances between bus stops improved the operational speed and punctuality. Number of passengers of Key Route Bus System has been decreasing in recent years although the rate is smaller than the passenger demand for the other bus services in the city. The authors conclude this relatively less decrease as higher service level diminishes the decrease in the number of passengers.
- Key Route Bus has positive impacts of improving the road capacity and hence decreasing the environmental load.
- Key Route Bus System does not demonstrate any positive impact of Transit Oriented Development or in other words change in population distribution and location of other sort of urban facilities are not showing any trend that supports the Transit Oriented Development along the BRT alignment.

For Guideway Bus, major results can be summarized as below:

- Elevated track provides high operational speed and punctuality obviously as a result of the complete separation from road traffic and signals. While operating on the ground level sections punctuality is also maintained in the peak hour.
- High service level of Guideway Bus System attracts many passengers and the increase rate in passenger demand is higher than the rate of the population increase.
- For implementing Guideway Bus Systems in Japan, legal regulation makes the operation system rather complex which then leads to the increase in operation costs of the elevated track section and furthermore fare system also becomes more complex.

Bus Rapid Transit Systems are regarded as good options of public transport as they provide better services with higher speed and meet higher capacity compared with the traditional buses. BRT systems evidently demonstrate low initial and operational costs per km compared to the railways. They also generate less environmental load because of shift from car users and improved speed on the bus network. Therefore BRT has been acknowledged as one of the best solutions in the developing countries where there is a growing passenger demand and limited financial resources especially effective in the cases requiring immediate transport network improvements.

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