Identification and Modeling of Influential Factors on Ridership in a New Bus Rapid Transit Based Transit-Oriented City in South Korea

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ABSTRACT

Multi-functional Administrative City (MAC) is a new planned city 100 miles south of Seoul which is developed to relocate 36 Governmental Offices and 16 Governmental Research Institutes from the Capital to stimulate balanced national development. MAC is a project area in Sejong City surrounded by four other cities. The total population of the five cities combined in 2013 are 3.2 million people, and the total area is 3,406 ㎢.

MAC consists of 22 walking friendly residential zones placed along the inner circular Bus Rapid Transit (BRT) corridor in which 65.6% of population and 82.4% of land for commercial and business use are concentrated in 500 meter walking distance. 73% of respondents of survey walk to BRT station. 47% of the respondents can reach BRT station in 5 minutes, and a total of 74% can reach the station in 10 minutes. Almost 70% of the respondents chose the close proximity and a good right-of-way as the reason for using BRT. With well-planned exclusive running ways, the BRT shows high traveling speed of 46.8km/h in 31.2km section. Since the beginning of the BRT operation in April 2013, the maximum ridership in a given month has tripled in 7 months from 1,828 persons per day to 5,674 persons per day.

Despite of the city having good environment and infrastructure such as the exclusive BRT running ways, a few implementations need to be made to achieve “State-of-the-art image” to be comparable to the world renowned BRTs. These include high-capacity articulated vehicle with multiple doors, station with amenities, and off-board fare collection system. The survey taken from the MAC residents showed that “travel speed” was the most satisfying element and “State-of-the-art image” was the most dissatisfying element.

The “travel speed” is the most influential element for ridership as well as for satisfaction impression of the BRT. A binary logistic regression analysis developed from the survey results indicates that the ridership is highly sensitive to the difference in travel time between the BRT and a private car. When the relationship between the mode share and travel time ratio of a private car and the BRT (i.e. travel time of private car over travel time of BRT) is applied to the future travel speed obtained from a Visum program, the prediction of mode share of private cars in 2030 is 29.05% which is under the target mode share of 30% established as the policy goal of the transit oriented city, MAC.

Given that the target population in MAC is expected to grow 0.5 million by 2030, BRT travel time will be increased due to more frequent stops and longer dwelling times at stations with the increased ridership. Therefore, the improvement for vehicle, station, and fare collection system is recommended to resolve the dissatisfaction of not having the “state-of-the-art image” in MAC’s BRT and also to prevent the decrease in travel speed which is the most desired and the most influential element for BRT ridership.

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CHAPTER 1. INTRODUCTION

1.1 Background

According to the Global Bus Rapid Transit (BRT) Data (ALC-BRT et al, 2014), BRTs are operated in 168 cities around the world and they carry 30.8 million people per day. The appearance and performance of each BRT are different with respect to the area, and the BRT systems have a variety of components implemented. However, BRT in a new planned city of South Korea is a unique case. The city is planned as a BRT based Transit Oriented City from the scratch.

New city in Korea, Multi-functional Administrative City (MAC)

MAC is a new planned city almost 100 miles south of Seoul which has been developed to relieve the severe concentration in the Korean capital region and to promote a balanced national development. 36 central governmental offices including the Prime Minister's office have been moved to this city since 2012. This city planning was completed in 2006, and the construction has taken place since 2007. The moving-in for the first residential area, "First town" started in the late 2011, and the target population of this city is 0.5 million by 2030.

Transit and walking oriented urban structure of MAC

One of the unique features of this city that influences travel behavior of the citizen in MAC is that it consists of the twenty-two walking friendly residential zones clustered along the main transit corridor. Each of these residential zones has about 20,000 people on average and has primary public facilities such as neighborhood parks, community center, elementary school, middle school, high school, as well as private commercial facilities like grocery stores and restaurants at the center of each area as shown in Figure 1-1-1. Because the facilities are located within walking distance in each residential zone, people who are living in the zones do not need to use their cars and can walk to complete their daily activities. This is especially beneficial for students because they do not need to rely on cars anymore. Therefore, most of the traffic demands for schools and daily activities can be reduced in each residential zone.

Traveling between the residential areas is easily connected through the main BRT transit corridor. There are two circular highways in MAC as shown in Figure 1-1-1. Outer circular highway works as a bypass while the inner circular highway is a main corridor for connecting the residential zones in MAC which is implementing the BRT lane in the center lanes with a high-level of right of way.

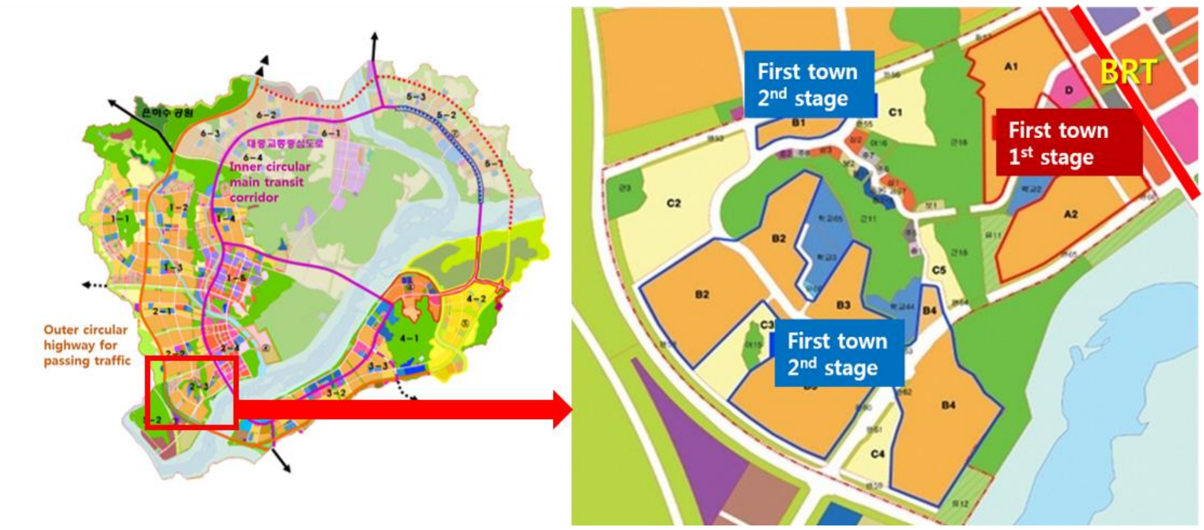


Figure 1-1-1. MAC's circular urban structure and typical residential zone (First town) shape in MAC (MACCA, 2011)

* First town is a residential zone along the BRT corridor which has a population of 20,000. 1st stage is completely included in the 500m radius from the BRT station and 2nd stage is beyond the range. In the middle of First town, parks, commercial facilities, and elementary adminstrative facilities are surrounded with housing complexes.

Inner circular BRT transit corridor

As shown in Figure 1-1-2, the outstanding feature of MAC is its circular urban shape clustered along the inner circular BRT transit corridor of which length is 22.9km. Most of the houses and jobs are concentrated along the corridor. Especially, government complex, local government offices, governmental research institutes, colleges, and industrial complex are placed near BRT stations in the inner circular BRT transit corridor. In addition, most of the houses and the business and commercial buildings in MAC are within the 500m walking radius of the BRT station. The inner circular BRT transit corridor has six road lanes which are composed of two BRT lanes and four general purpose lanes. This city is planned as a transit and walking oriented city. Therefore, it has a policy goal to control the mode share of private car under 30%. Thus, the road lanes for cars in the main corridor are limited to four lanes in both directions and the other arterials also have only four lanes. When compared with the number of lanes of main corridor in other new cities in South Korea, the number of non-BRT lanes might be insufficient because this corridor is highly concentrated with housing complexes and commercial buildings. With this in mind, the inner-city transportation for MAC will heavily be dependent on the BRT of the main transit corridor.

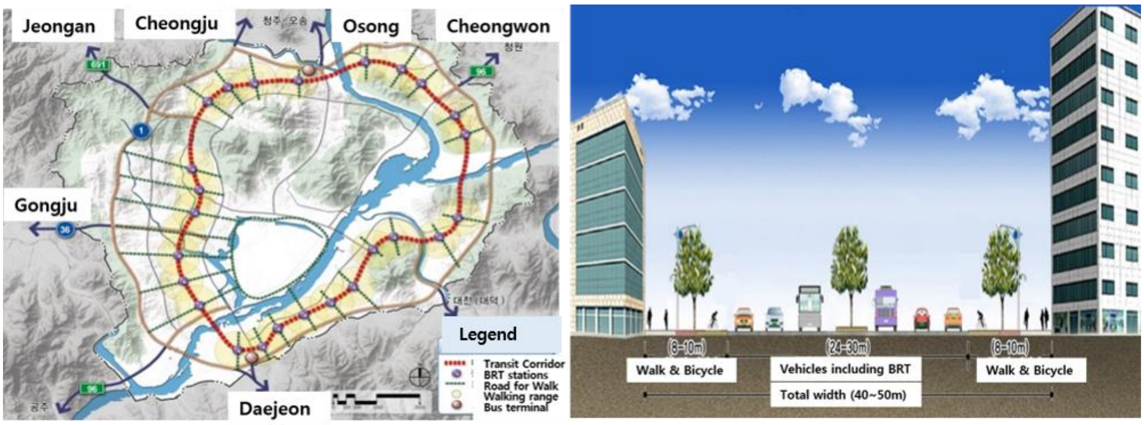


Figure 1-1-2. The shape of MAC's inner circular BRT transit corridor and the cross-section of the corridor (MLTM, 2006; MACCA, 2006)

1.2 Purpose and Scope

As shown in the urban shape and the cross-section of the inner circular BRT transit corridor of MAC, BRT is designed to be the most important travel mode and the level of utilization of the BRT would determine the future traffic condition. The purpose of this thesis is to identify the factors influencing the increase of BRT use and to predict the future traffic condition influenced by those factors. In addition, the result of this thesis intended to determine the methods for improving the BRT of MAC.

1.3 Thesis overview

Chapter 2 (Literature review) reviews the prior research about BRT's features and the influence of the features. Chapter 3 (Methodology) presents a proposed framework to identify the important element of the BRT of MAC and explains each method used for identifying the important elements and predicting the future travel behaviors and situations. Chapter 4 (Analysis of the BRT of MAC and the status of BRT use) introduces the unique feature of MAC and its BRT, and people's travel behavior in MAC which can influence the pattern of BRT usage in MAC. Chapter 5 (Identification of elements influencing satisfaction for the BRT of MAC) identifies the most influential elements of BRT for the satisfaction level for BRT of MAC by using revealed preference survey and binary logistic regression analysis. Chapter 6 (Identification of elements influencing BRT ridership in MAC) extracts the influential elements for the ridership of MAC's BRT by utilizing surveyed preferences for the important elements contributing the increase of BRT use. Also, by utilizing logistic regression analysis, this chapter produces the logistic regression equation for the relationship between the probability of the increase of BRT ridership and the ratio of travel times spent between usage of private car and BRT. In Chapter 7 (Prediction of future mode share and travel time), the relationship between

BRT ridership and travel mode share is introduced and the future mode share and travel speeds in both BRT lanes and the other lanes in the inner circular BRT transit corridor are predicted by using the Visum program. Finally, Chapter 8 (Conclusion and Recommendation) summarizes the most important element of BRT in MAC and its influence on mode share and travel speed in the future, and it suggests the needed recommendation and further study for MAC's BRT.

CHAPTER 2. LITERATURE REVIEW

2.1. Researches for important element for BRT

Recent research efforts (Currie and Delbosc, 2011; Galicia et al, 2009; Taylor et al, 2009; Hinebaugh, 2009; Hensher and Golob, 2008; Hensher and Li, 2012; GAO, 2012; Weinstock et al, 2011; Levinson et al, 2003) have analyzed the numerous BRT cases in the U.S. and the other continents and have tried to find the common features of BRT.

As shown in Table 2-1-1, Hensher and Li (2012) identified 11 sources of systematic variations that have statistically significant impact on daily passenger-trip numbers by reviewing 46 BRT systems opened between 1974 and 2010 from 15 countries. They reported 78.3% of 46 BRT systems implemented bus-only roadways, and only 47.8% has implemented signal priority or grade separation at intersections. As Table 2-1-2 from GAO (2012) indicated, the U.S. shows a very low implementation of segregated bus ways for BRT. Only 3 of the 20 implemented over 30% in segregated bus-only roadways of total bus ways length.

Most of the systems have specially designed vehicles which are distinguished from conventional buses. Rail-like features such as high capacity, outstanding appearance, multiple doors, and state of the art ITS systems are implemented in the BRT vehicles. In the cases of the U.S. BRTs, all of the 20 analyzed vehicle systems equipped with rail-like features.

Regarding the stations shown in Table 2-1-1, 76% of 46 BRT systems have real-time information system, and 71% implement distinguished stations from conventional bus stations. Especially, BRT stations in South America are similar to the rail stations in size and equipped facilities.

A half of 46 systems analyzed by Hensher and Li (2012) and 7 of 20 U.S. BRTs of GAO (2012) have implemented off-board fare collection system which contributed to high quality transit image and travel time saving by fast boarding and alighting (Levinson et al, 2003).

Branding is applied to over 70% of the world's 46 systems and to all 20 U.S. systems. Outstanding design and image are applied to vehicles and stations. BRT website and smartphone applications are developed. One city's special BRT system has its own nick name like BusPlus in Albany, NY and the BRT system's image is utilized as the city's representative image and tourist attraction.

Table 2-1-1. Profile of 46 BRT systems in the world (Hensher and Li, 2012)

Quantitative variables	Unit	Mean	Standard deviation
Fare	(US$2,006)	1.04	1.30
Total length of BRT network	Kilometers	27.38	22.90
Number of existing trunk corridors	Numbers	2.30	2.27
Number of stations	Numbers	38.33	43.96
Average distance between stations/population density	Meters/ (persons/sqare meter)	0.69	0.95
Average commercial speed	Kilometers per hour	25.68	12.40
Average peak headway	Minutes	3.35	2.80
Trunk vehicle length	Meter	16.69	3.85
Qualitative variables : whether the BRT system has:		**Percentage of "Yes" (%)**	
Segregated bus ways for bus-only roadways		78.3	
An integrated network of routes and corridors		52.2	
Enhanced station environment		71.7	
Pre-board fare collection and fare verification		47.8	
At-level boarding and alighting		54.3	
Competitively-bid and transparent contracts and concessions		26.1	
Signal priority or grade separation at intersections		47.8	
Distinctive marketing identity for system		71.7	
Quality control oversight from an independent entity/agency		41.3	
High-quality customer information		79.1	
Modal integration at stations		23.9	

Table 2-1-2. Profiles of 20 US BRT systems completed since 2005 (GAO, 2012)

Project (Location)	Running ways (at least 30 percent of route length)		Station amenities (by number of amenities)		Fare collection (off board)	Vehicle features (at least 5 of 11 features)	Branding and marketing	ITS features (at least 3 of 6 features)
	Dedicated	Semi-dedicated	4-6	7-12				
Healthline (Cleveland, OH)	*			*	*	*	*	*
Flanklin Emx (Eugene, OR)	*			*	*	*	*	*
Gateway Emx (Eugene, OR)	*	*		*	*	*	*	*
RapidRide A (Seattle, WA)		*	*			*	*	
M15 (New York, NY)		*				*	*	
RTC Rapid (Reno, NV)				*	*	*	*	*
BusPlus (Albany, NY)			*		*	*	*	*
Metro Express 44 (San Joaquin, CA)			*		*	*	*	*
Boulder Hwy. Expresss (BHX) (Southern NV)			*		*	*	*	
Troost MAX (Kansas City, MO)			*			*	*	*
The Rapid (Livermore, CA)			*			*	*	*
RapidRide B (Seattle, WA)			*			*	*	
Mountain Links (Northern AZ)			*			*	*	
Metro Rapid Gap Closure (Los Angeles, CA)						*	*	*
Metro Rapid 741 (Los Angeles, CA)						*	*	
Total (out of 20)	3	3	8	4	7	20	20	9

2.2. Research for providing guidelines for integrating key features of BRT

With the research regarding the features of BRT and the elements influencing the BRT performance, there have been opinions for implementing the full-featured BRT for realizing the expected ridership and performances of BRT (Deng and Nelson, 2013; Weinstock et al, 2011), and there have been efforts to generate the integrated guideline and instruction for the successful implementation of BRT through the studies of world-wide BRT implementation cases. (Weinstock et al, 2011; Galicia et al, 2009)

Weinstock et al. (2011) tried to find the main reasons why the American BRT systems have fallen short of global best practice, and suggested the BRT Standard through comparing several BRTs in U.S. with international best practices. The standard shows the BRT features that impact on bus speed, passenger travel time, customer comfort, and ridership. Table 2-2-1 in the following shows the criteria and their scores adopted in the BRT Standard. A total score of 85 or above classifies a BRT system as gold, a score of 70–84 as silver, and a score of 50–69 as bronze. They reported the four highest ranking international BRT systems: *Gold*: Bogotá (93), Guangzhou (89) / *Silver*: Johannesburg (79), Ahmedabad (76).

Table 2-2-1. BRT Standards (Weinstock et al, 2011)

	Item	Max. score
Service planning(42)	Off-vehicle fare collection	7
	Multiple routes use same BRT infrastructure	4
	Peak period frequency	4
	Routes in top 10 demand corridors	4
	Integrated fare collection with other public transport	3
	Limited and local stop services	3
	Off-peak frequency	3
	Part of (planned) multi-corridor BRT network	3

	Performance-based contracting for operators	3
	Enforcement of right-of-way	2
	Operates late nights and weekends	2
	Operational control system to reduce bus bunching	2
	Peak-period pricing	2
Station design and station-bus interface (12)	Platform-level boarding	5
	3+ doors on articulated buses or 2+ very wide doors on standard buses	4
	Multiple docking bays and sub-stops	3
Infrastructure (30)	Bus lanes in central verge of the road	7
	Physically separated right-of-way	7
	Intersection treatments (elimination of turns across bus ways and signal priority)	4
	Physically separated passing lanes at station stops	4
	Stations occupy former road/median space (not sidewalk space)	3
	Stations set back from intersections (100 ft minimum)	3
	Stations are in center and shared by both directions of service	2
Quality of service and passenger information systems (8)	Branding of vehicles and system	3
	Safe, wide, weather-protected stations with artwork (≥8 ft wide)	3
	Passenger information at stops and on vehicles	2
Integration and access (8)	Bicycle lanes in corridor	2
	Bicycle sharing systems at BRT stations	2
	Improved safe and attractive pedestrian access system and corridor environment	2
	Secure bicycle parking at station stops	2

Galicia et al. (2009) recommended sorted BRT features that could be applied to each different deployment stages like the following Tables 2-2-2 and 2-2-3. Because of the various environments in which the BRT system are implemented, the features should be selected according to each region's budget, local users, and traffic and corridor characteristics, and it should be combined to produce the maximum ridership and operating speed. The BRT infrastructural features and operational features are divided by cost, engineering sophistication, and implementation time frames and are recommended at different stages of deployment.

Table. 2-2-2 Recommended BRT Infrastructural Features at Different Stages of Deployment (Galicia et al, 2009)

<table>
<tr><th colspan="2" rowspan="2">INFRASTRUCTURE FEATURES</th><th>phase 1</th><th>phase 2</th><th>phase 3</th></tr>
<tr><th>3,000 to 9,300 pax/trip/day</th><th>3,500 to 26,000 pax/trip/day</th><th>120,000 to 1,450,000 pax/trip/day</th></tr>
<tr><td colspan="5">GUIDEWAY AND LANE IMPROVEMENT</td></tr>
<tr><td colspan="2">Mixed-flow</td><td>*</td><td></td><td></td></tr>
<tr><td colspan="2">Dedicated guideway</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Contra-flow way</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td rowspan="3">Segregated land or exclusive guideway</td><td>Below grade</td><td></td><td></td><td>*</td></tr>
<tr><td>At grade</td><td></td><td></td><td>*</td></tr>
<tr><td>Aerial</td><td></td><td></td><td>*</td></tr>
<tr><td colspan="2">Queue jumper</td><td>*</td><td>*</td><td></td></tr>
<tr><td colspan="2">Overpass lane</td><td></td><td></td><td>*</td></tr>
<tr><td colspan="2">Median lane runway</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Curb lane</td><td>*</td><td></td><td></td></tr>
<tr><td colspan="2">Curb extension</td><td>*</td><td></td><td></td></tr>
<tr><td colspan="5">STATIONS</td></tr>
<tr><td colspan="2">Enhanced shelters with seats and lighting</td><td>*</td><td>*</td><td></td></tr>
<tr><td colspan="2">Air conditioning/heater</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Level platforms</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Other amenities(route & schedule, vending machines, telephones)</td><td></td><td></td><td>*</td></tr>
<tr><td colspan="2">Pedestrian crosswalks with signal</td><td>*</td><td>*</td><td></td></tr>
<tr><td colspan="2">Pedestrian bridge access</td><td></td><td></td><td>*</td></tr>
<tr><td colspan="2">Automatic passenger counter</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="5">PARK-AND-RIDE FACILITIES</td></tr>
<tr><td colspan="2">Open lot parking</td><td>*</td><td>*</td><td></td></tr>
<tr><td colspan="2">Multi-level parking</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Transfer areas(inside buildings)</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Bicycle parking</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Taxi stands</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td colspan="5">SURROUNDING LAND USE</td></tr>
<tr><td colspan="2">Sidewalk condition improvements</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Security systems near stations</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Mixed land use near station</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Commercial activities around stations</td><td></td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Clustered business facilities</td><td></td><td></td><td>*</td></tr>
</table>

Table. 2-2-3 Recommended BRT Operational Features at Different Stages of Deployment (Galicia et al, 2009)

OPERATIONAL FEATURES	phase 1	phase 2	phase 3
	3,000 to 9,300 pax/trip/day	3,500 to 26,000 pax/trip/day	120,000 to 1,450,000 pax/trip/day
VEHICLES			
40~60ft articulated	*	*	
80ft double articulated			*
Diesel, CNG or electric vehicle	*	*	*
Hybrid vehicle		*	*
Low-floor vehicles		*	*
Multiple entrance-exit doors			*
Wi-fi service			*
INTELLIGENT TRANSPORTATION SYSTEM			
Transit signal priority	*	*	
Automatic vehicle location		*	*
Real-time information system(at stations)		*	*
Real-time information system(on board)			*
Collision warning			*
Precision docking			*
Lane-assist system			*
Automatic steering-guidance system			*
Automatic speed and spacing control system			*
Voice and video monitoring			*
FARE COLLECTION			
On-board fare collection	*	*	
Pre-board fare collection	*	*	*
Cash payment	*		
Magnetic strip cards		*	
Smart cards		*	*
SERVICE AND OPERATION			
Marketing identity	*	*	*
Reduced number of stops	*	*	*
Route length extension		*	*
Increased coverage area with multiple routes			*

High service frequency		*	*
Feeders system		*	*
On-time performance monitoring		*	*
OPERATION SPEED			
Operating speed <20mph	*		
Operating speed >20 and <30mph		*	
Operating speed >30mph			*

In addition, recent research efforts such as Wirasinghe et al. (2013) and Hidalgo and Carrigan (2010) incorporated on administrative and cooperative issues inner and between agencies and the other stakes holders for implementing BRT.

2.3. Performance of BRT

Hidalgo and Gutierrez (2013) incorporated the performances of BRT and BHLS (Bus of High Level of Service) systems around the world implemented up to 2011. They defined some performance indicators such as commercial speed, peak section load, and productivity, and they showed the maximum performance cases which is shown in Table 2-3-1. Other research compared the performances of various BRT systems around the world with various indicators such as total length of BRT network, stop spacing, total passenger demand, peak loads, daily passenger boarding per bus-km, peak speed, frequency, service span, capital cost per km, and environmental indicator such as the residential and employment density and car ownership. (Hidalgo and Carrigan, 2010; Currie and Delbosc, 2011; Hensher and Li, 2012; Wang et al, 2012)

Table 2-3-1. Maximum values for some performance indicators in selected BRT systems (Hidalgo and Gutierrez, 2013)

Performance indicator	Definition	Value (year)	System, city	System features
Commercial speed	Distance/time as perceived by the user on board (km/h)	42km/h (2011)	Metrobus, Istanbul Turkey	Fully segregated busway on expressway, stations every 1.1 km

Peak section load	Passenger/hour/direction (pphpd)	45,000 pphpd (2011)	TransMilenio, Bogota, Colombia	Median busway, level acess stations with 5 platforms - local, express, 7 standees per square meter, dense urban area
Infrastructure productivity	Passenger boardings/km of busway	35,800 (2011)	Guangzhou BRT, China	Median busway, with long station, overtaking lanes, open operation 40 routes, very dense urban area
Capital productivity	Passenger boardings /bus/day	3,100 (2010)	Macrobus, Guadalajara, Mexico	Median busway, overtaking lanes relatively dense, mixed use urban area
Operational productivity	Passenger boardings/ bus-km	13.2 (2010)	Metrovia, Guayaquil, Equador	Median busway, dense urban area, very low fare (USD 0.25 per trip)

2.4. Expected Effect for BRT ridership by each element

Kittelson & Associates et al. (2007) illustrated the influence of each element of BRT for the ridership of BRT as shown Table 2-4-1. However, they do not justify the method providing the ridership improvement the estimations.

Table 2-4-1. Predicted ridership increase by improvement of BRT elements (Kittelson & Associates et al, 2007)

Component	System 1 (High-Level)		System 2 (Minimal)	
Running Ways	Grade-separated busway	20%	All-day bus lanes	5%
Stations	Unique, attractively designed	2%	Unique, attractively designed	2%
	Illumination	2%	Illumination	2%
	Telephones/security phones	3%	Telephones/security phones	0%
	Passenger amenities	3%	Passenger amenities	0%
Vehicles	Uniquely designed vehicles	5%	Uniquely designed vehicles	5%
	Wide multi-door acess	5%	Wide multi-door access	0%
	Low-floor vehicles	5%	Low-floor vehicles	0%
Service Pattern	All day service span	4%	All-day service span	4%
	High-frequency service	4%	High-frequency service pattern	4%

	Clean, simple service pattern	4%	Clean, simple service pattern	4%
	Off-vehicle fare collection	3%	Off-vehicle fare collection	0%
ITS Applications	Passenger information at stops	7%	Passenger information at stops	7%
	Passenger information on vehicles	3%	Passenger information on vehicles	0%
BRT Branding	Vehicles and stations	7%	Vehicles and stations	7%
	Brochures and schedules	3%	Brochures and schedules	3%
Subtotal		80%		43%
Synergy		15%		0%
Total		95%		43%
Bias (10 minutes * Total) (in minutes)		9.5		4.3
Elasticity increment (0.25 * Total)		0.24		0.11

Most research quantifying the effects of BRT implementation for travel mode shift to BRT used preference survey, or modelling. Wang et al. (2013) studied six BRT corridors in China and used binary logistic analysis to assess the impacts of modal shift caused by BRT implementation. They found that the travel time saving increases the probability of modal shifts to BRT up to 57%. Hensher and Li (2012) found that fare level and the length of headway show high negative elasticity parameters for the BRT trips by using random effects regression model.

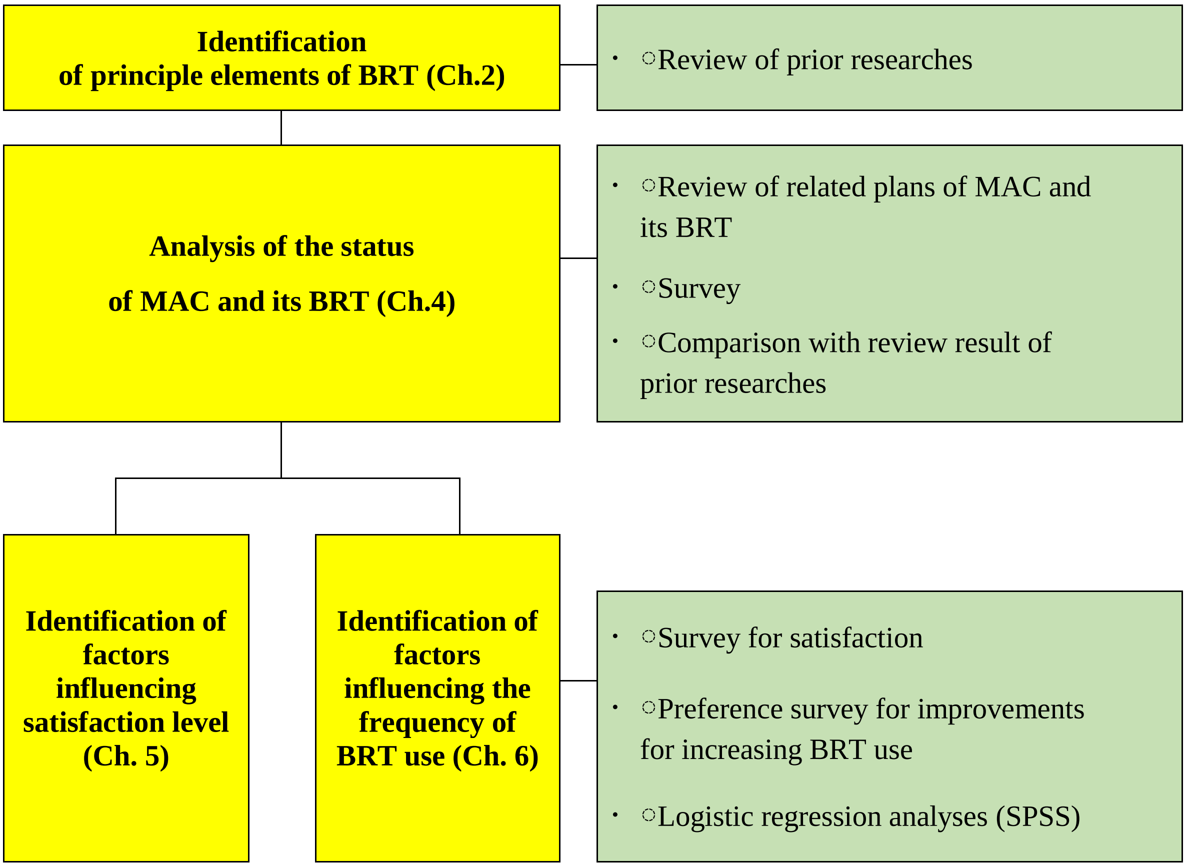
2.5. Contribution

By now, most of the research on BRT in a specific area are regarding the prediction of the effect on ridership, travel mode share, land use, environment, and economy of existing city by adopting new BRT. However, the outstanding difference of this research is the feature and the magnitude of the research area which was a new city having a planned population 0.5 million. As noted, the new city, MAC was planned as a BRT based transit-oriented city from the scratch. MAC has a highly concentrated circular main transit corridor equipped with a BRT in the center lanes within the 500m radius. The total road capacity of the inner circular BRT transit corridor and the other arterials is limited by a policy goal which is set to control the mode share of private cars under 30%. This thesis made an effort to identify the factors influencing the increase of BRT use out of the unique urban structure and also to predict the future traffic condition influenced by these factors. In order to do so, the feature of this city's inner circular BRT transit corridor is analyzed. Next, a variable such as the ratio of travel times between the private cars and BRT is used for identifying the behavior feature of residents in the BRT corridor where the road capacity is limited for private cars and no competitive transit mode is present. The result obtained from this research is expected to be influenced by these unique features of the new city. The result will be utilized for determining improvement suggestions for the BRT of MAC and also as a reference for urban transportation planning of this type of new cities.

CHAPTER 3. METHODOLOGY

3.1. Framework

To identify the factors influencing the ridership of the BRT of MAC, as shown in Figure 3-1-1, the first step is to find out the standard of good BRT to assess the BRT of MAC. Next, the BRT of MAC is compared with the features of the world's renowned BRTs in order to identify the strong and weak elements of MAC's BRT. Also, the preference of the residents of MAC for the strong and weak elements were surveyed. The relationship between the ridership and the influential factors is identified by analyzing the features of travel behavior of the people with the binary logistic regression analysis. Then by using the relationship and the simulation program, the future traffic condition is predicted which will be used for the improvement suggestion for the BRT of MAC.



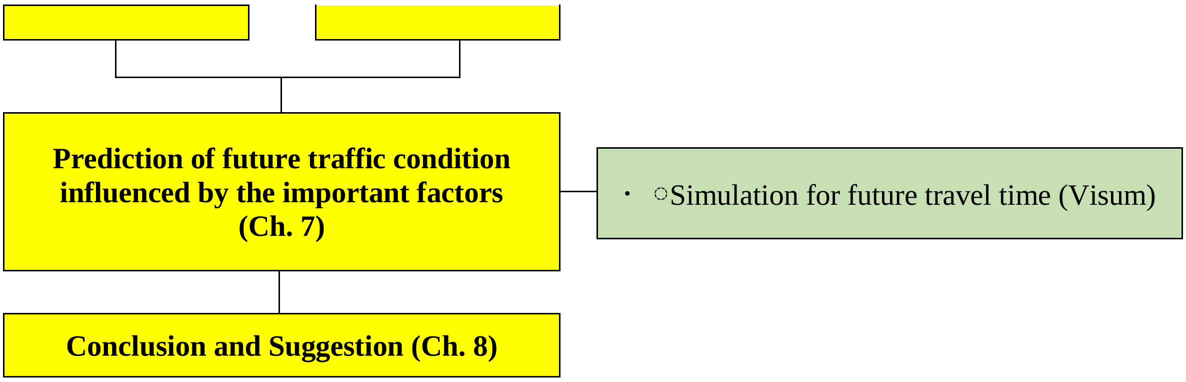


Figure 3-1-1. Methodology framework

3.2. Analysis of the status of MAC's BRT

3.2.1. Identification of important elements of BRT through reviewing the prior research

By reviewing prior research efforts (i.e., Currie and Delbosc, 2011 ; Galicia et al, 2009 ; Hensher and Golob, 2008 ; Hensher and Li, 2012 ; US GAO, 2012 ; Weinstock et al, 2011) mentioned in Chapter 1, factors affecting BRT ridership was grouped into 3 categories: environments, infrastructures, and operation.

Environmental elements are socio-demographic elements such as population, density, income level, and car ownership, and urban structural elements such as geographical/physical features, mixed land use and commercial activities which can not be controlled by the transit agencies. (Wirasinghe et al, 2013; Cervero and Kang, 2011; Galicia et al, 2009; Bajracharya, 2008; Yagi and Mohammadian, 2008; Taylor et al, 2009).

Infrastructural elements include network or coverage, running ways, vehicles, stations, fare collection systems, and branding. (Hensher and Li, 2012; McDonnell and Zellner, 2011; GAO, 2012)

Finally, the operational and administrative elements are service frequency, speed, service hours, fare, quality control oversight from an independent agency, performance-based contracting for operators, and enforcement of right of way which are controlled by agency to meet the using demand and to optimize the efficiency. (Weinstock et al, 2011; Hensher and Li, 2012)

3.2.2. Identification of the status of MAC's BRT

To analyze the status of MAC's BRT in terms of the important elements found by prior research efforts, the documents related to MAC's planning and construction such as MAC's Construction General Plan (MOCT, 2006), MAC's Development Plan (MACCA, 2006), MAC's BRT Principle Plan (KLC, 2007), and MAC Public Transportation System Establishment Research (MAC, 2011) were reviewed and the recent performance data such as ridership and travel speed were acquired with the cooperation of MACCA. In addition, residential survey was performed to acquire data regarding the public usage of the BRT in MAC.

3.3. Survey of MAC's residents

3.3.1. Survey area

Currently, MAC is undergoing construction, and the only settled area as a unit residential zone is First town. First town features a typical residential zone character which has a population of almost 20,000 people. First town is located along the inner circular BRT line in the south-western area of MAC which has a total of 22 unit residential zones placed along the inner circular BRT transit corridor. This zone shows the typical shape of MAC's residential zones which is appropriate to accommodate all the expected number of citizen in the future.

3.3.2. Sample size and adjustment

The survey was conducted in both the internet and on-the-spot. There were a total of 242 responses, but there were 45 inappropriate responses for the question about residential. Therefore, the total number of valid responses was 197, and it was approximately 1 % of the total number of First town residents in November, 2013 which was 19,698.

However, respondents of the age group below 20 showed a transitional pattern which will not be seen after one or two years. Students living in First town can attend their school by walking because First town has all level of schools from kindergarten to high school in the middle of the town. However, most of the residents in First town moved in from the nearby regions in late 2011 or early 2012, and many students still have not made a transfer to new school. Therefore, these students use the BRT frequently, and this travel pattern is bound to change in the upcoming 1 to 2 years. Therefore, the 34 responses from this age group below the age of 20 were removed from the survey analysis.

Among 163 samples, 59.5% samples were collected from the first stage apartment complex of First town which is located within 500m radius from BRT station and 40.5% was collected from the second stage which is located outside of 500m radius from BRT. This ratio of sample collected within the 500m radius from the BRT line is consistent with the ratio of the total housing of MAC located within the 500m radius from the BRT line.

3.3.3. Survey elements

3.3.3.1. Section 1. Socio-economic data

The collected data in the first section are socio-economic information which can influence the travel behavior of the people in MAC. The socio-economic parameters that are generally recognized as important elements that influence pattern of behavior using public transit are gender, living place, age, job status, income level, marriage status, education completed, household size, car ownership, type of residence, and place of employment.

3.3.3.2. Section 2. Travel behavior data

Section 2 of the survey has gathered data regarding the travel behavior such as trip purpose, primary and second mode for trip, trip frequency, and travel time with the primary trip mode.

3.3.3.3. Section 3. BRT usage data

In Section 3, people's BRT usage data were collected. The parameters include BRT usage frequency, purpose of BRT usage, travel mode before moving into MAC, departure and arrival station, travel mode for departure and from arrival BRT station, travel time for departure and from arrival station to destination, travel time on board, and reason of selecting BRT.

3.3.3.4. Section 4. Satisfaction level

In Section 4, the overall satisfaction level and the specific satisfaction level were recognized by travel speed, frequency, reliability, service hours, state-of-the-art image, vehicle, station, boarding time including payment (fare collection type), fare level, transfer, information system, and access to station. In addition, 1st and 2nd satisfactory elements and 1st and 2nd dissatisfactory elements among the total elements were defined to understand the comparative recognition of BRT users.

3.3.3.5. Section 5. Survey for influential element to increase BRT usage

Finally, in Section 5, the preferred elements needed to increase the BRT usage were found by survey. The people's response to the improvements were also included in the question.

3.4. Binary logistic regression analyses

The SPSS 13.0 software was employed to calibrate the binary logistic regression models which are generally used for identifying the factors affecting people's travel behavior such as ridership of transit and mode change to transit. By using the survey data, the binary logistic regression analysis method was utilized for identifying the important elements for overall satisfaction impression for BRT and for identifying the elements influencing BRT ridership.

3.5. Simulation for predicting future travel speed and mode share

The simulation method with the Visum program is used for predicting the future travel speed and mode share in the inner circular BRT transit corridor. In the inner circular BRT transit corridor where one lane for BRT and two lanes for the other modes (i.e., general vehicles) in one direction are present, the travel speed in the other lanes and mode share can be predicted. As the traffic increases, and if the travel speed of BRT is assumed to be constant, the travel speed in the other lanes and mode share are expected to be converged to a point with the relationship between the ratio of travel times between private cars and BRT and the mode share.

CHAPTER 4. ANALYSIS OF MAC'S BRT AND STATUS OF BRT USE

4.1. MAC's BRT system

MAC is a project area in Sejong City surrounded by four other cities. The total population of the five cities combined in 2013 are 3.2 millions, and the total area is 3,406 ㎢ as shown in the following Figure 4-1-1 and Table 4-1-1. MAC's BRT system is composed of an inner circular BRT line and five metropolitan BRT lines.

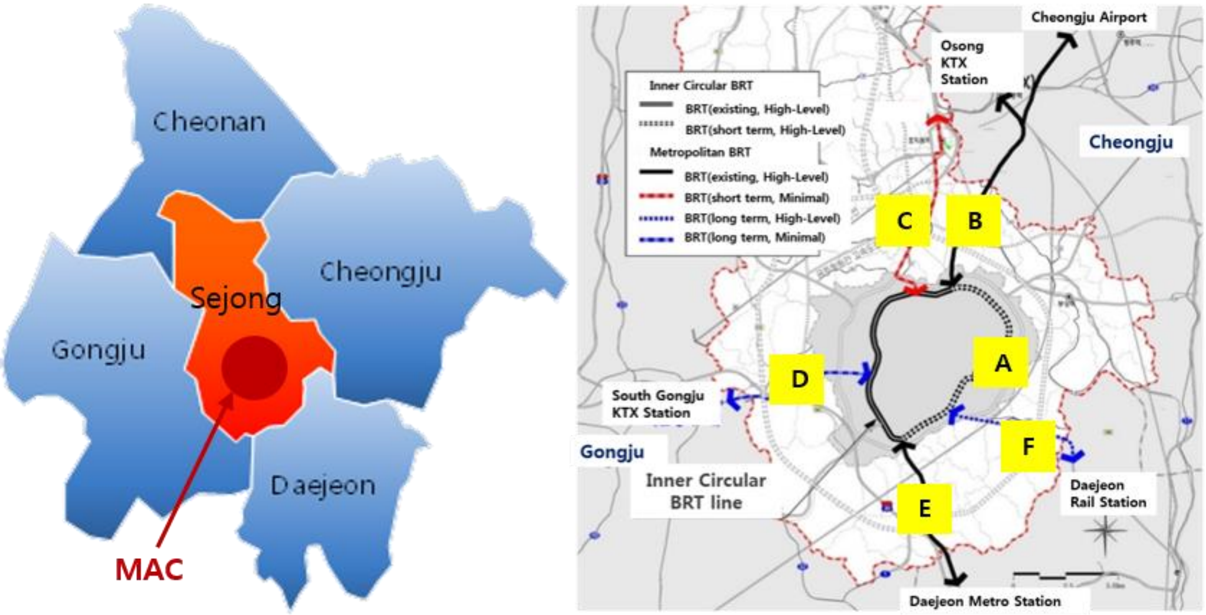


Figure 4-1-1. The surroundings of MAC and metropolitan BRT connection plan (Sejong Special-Governing City, 2013)

Table 4-1-1. The population and area of the cities surrouding MAC in 2013

	Sejong	Cheonan	Cheongju	Daejeon	Gongju	sum
Population	120,000	650,000	830,000	1,520,000	100,000	3,220,000
Area(㎢)	426	636	940	540	864	3,406

Metropolitan BRT connections

In the right map of the Figure 4-1-1, the B and E BRT lines connect between the inner circular transit corridor (A line) and the main transit points such as Osong KTX (Korean Train eXpress, the name of Korean high-speed rail) station and Banseok metro station of Daejeon Metropolitan City which have been operating since the late 2012. The BRT line connecting Osong (B line) is planned to be extended to Cheongju Airport in the upcoming future. The C line will connect the inner urbanized area in Sejong City and the D and F lines will connect nearby cities of west and east of MAC.

Integrated transfer systems

MAC's BRT system is connected to other motorized travel modes such as private vehicles and intercity buses by using five transfer centers and two bus terminals linked with BRT as shown by Figure 4-1-2, Table 4-1-2, and Table 4-1-3. People who use their private cars to come to MAC from other cities can park their car in the transfer center parking lot and use BRT to travel around MAC. Also, the users of intercity buses which connects to most of the country, can easily use BRT to travel around MAC. Non-motorized transportation such as bicycles is also linked with the BRT system like Table 4-1-4. In addition, it has been operating the free transfer system with Daejeon's bus and metro which has the highest demand for transfer among near cities since June, 2013.

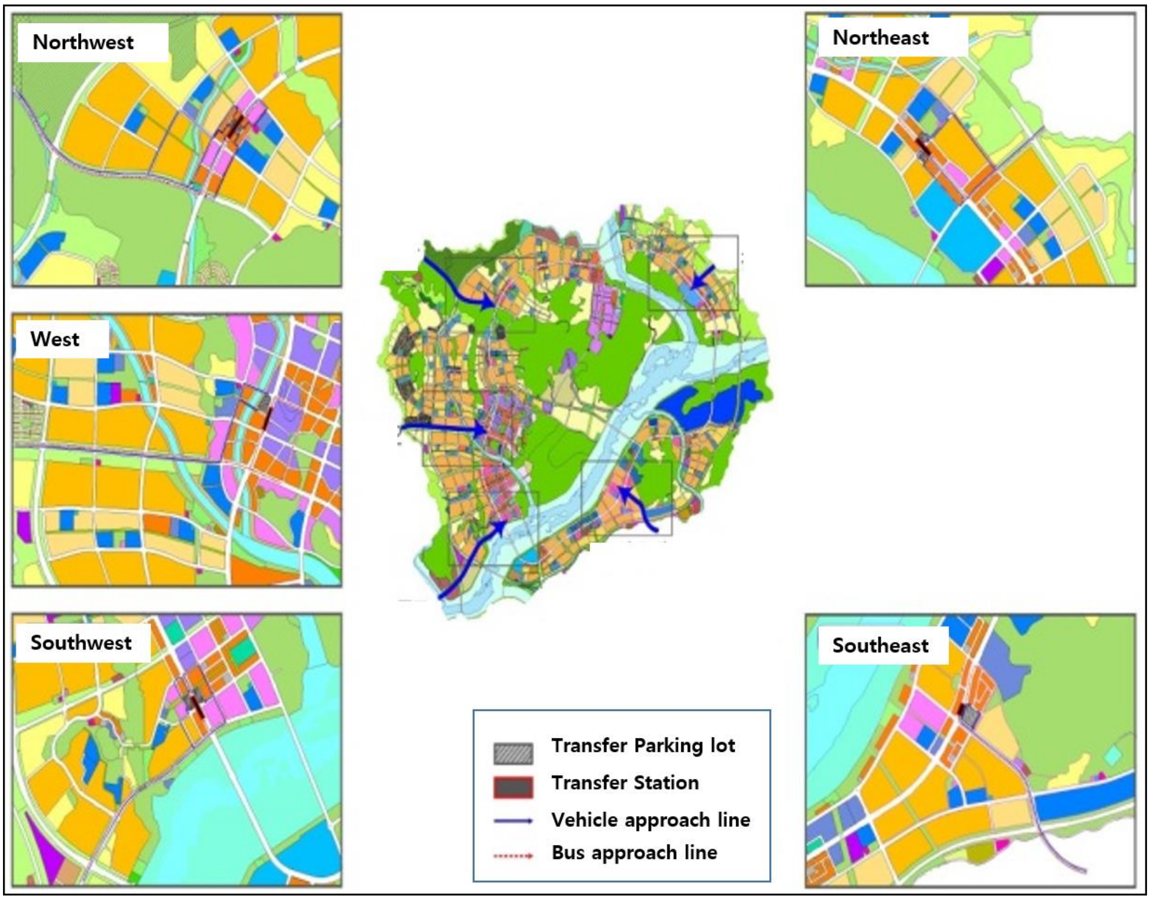


Figure 4-1-2. Location of Transfer Centers

Table 4-1-2. Transfer Parking Lot

Location		Size (㎡)	Parking capacity (cars)
1	Southwest	9,989	340
2	West	6,523	220
3	Northwest	5,882	200
4	Northeast	3,452	120
5	Southeast	10,838	360

Table 4-1-3. Intercity Bus Terminal

Bus Terminal	Size (m^2)	Transfer mode
North Terminal	15,823	Intercity bus
South Terminal	41,857	Intercity bus

Table 4-1-4. Public Bicycle implementation plan

	Pilot operation (2013～2014)	**Stage 1** (2015～2019)	**Stage 2** (2020～2029)	**Stage 3** (2030 and after)
Public bicycle	230	860	1,850	2,960
Bicycle rack	20	74	156	244

Inner circular BRT line

The length of the Inner circular BRT line is 22.9km, and it has 22 stations as shown in Figure 4-1-3. However, the BRT of MAC is currently operated only on the western half of the circle which is approximately 12.9 km in length and has 12 stations. It is connected with two metropolitan BRT lines (9.5km + 8.8km) ending at Osong KTX station in north and at Banseok metro station in south.

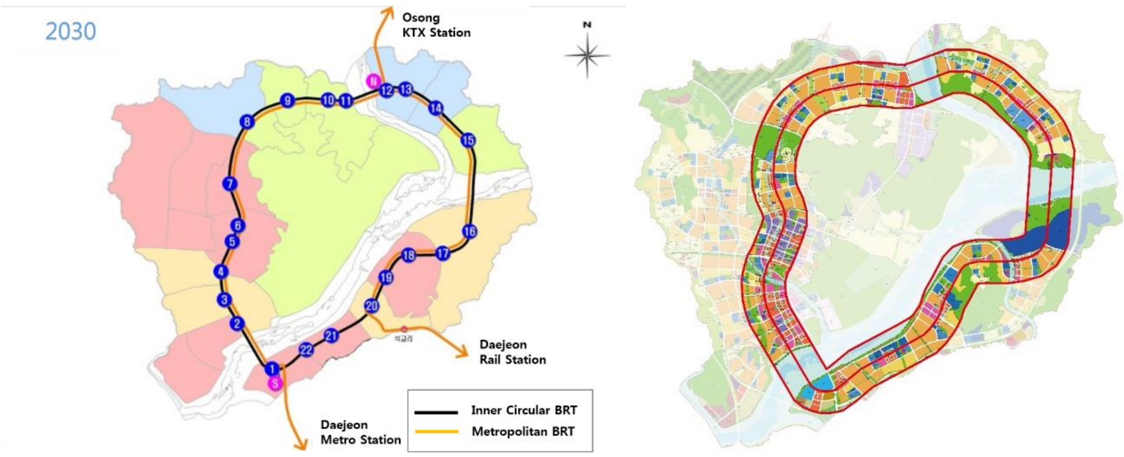


Figure 4-1-3. Main circular transit corridor and walking distance (500m) **range along the corridor**

As shown in the road cross-section of the inner circular BRT transit corridor in Figure 1-1-2, this corridor has 6 lanes in both directions which consist of two BRT lanes in the center and the other four lanes are for other vehicles. Within the walking distance, which can be defined as 500m radius from the BRT stations shown in the right map of Figure 4-1-3, 323,088 persons (65.6%) out of the total population of 500,000 persons occupy the region, and 1,346,572㎡

(82.4%) of 1,634,327㎡, total land for commercial and business are located along this inner circular BRT transit corridor.

According to survey result regarding the BRT usage (Figures 4-1-4 and 4-1-5), 73% of the respondents walk to their departure BRT station. 13% of the respondents use bus and 5% use bicycle to reach their BRT station. Regarding the travel time, 47% of the respondents can arrive to BRT station in 5 minutes and 27% in 10 minutes. As a whole, 74% reach the BRT station in 10 minutes. The average travel time to the departure BRT station is 10.8 minutes.

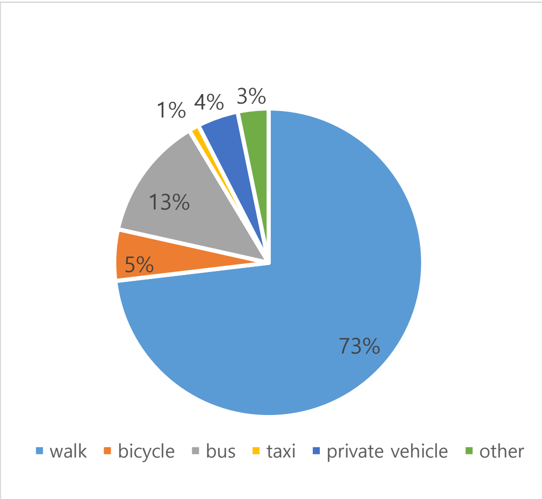


Figure 4-1-4. Travel mode for station

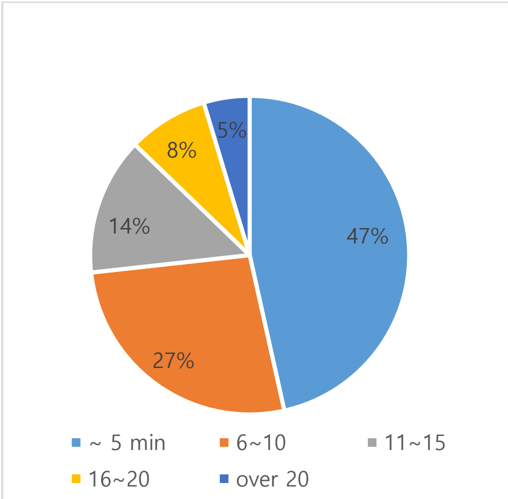


Figure 4-1-5. Travel time for station

Mu and Jong (2012) emphasized several influential factors of transit oriented development (TOD) from reviewing numerous research. The factors include urban design (including architecture aesthetics, public space and pedestrian friendliness), governance (including transport service coordination and pro-active town planning), land use (including factors such as density and diversity), strategies on restricting automobile use (for instance, congestion pricing and parking restriction), and transit service quality and management of the real estate market.

MAC implemented most of the factors of "urban design" and "land use" of TOD shown in Mu and Jong (2012) and as a governmental lead project, it has a good legal, administrative and financially supportive foundation for the factor of "governance", "strategies on restricting automobile use", and "transit service quality and management of the real estate market".

4.2. BRT Usage Status

As shown in Table 4-2-1, since the start of BRT operation in April, 2013, the ridership of BRT has increased up to three times in 7 months without a big increase in the population in MAC. Although there was a little decrease in ridership during August and September due to the vacation and holiday season, the maximum ridership in a month has continuously increased up three times from 1,828 to 5,674 while the population has increased by only 24.6% in the same period. The ridership of BRT has largely increased after the start of a free transfer between the BRT of MAC and bus and metro of Daejeon in June 1, 2013 and the start of the 2nd relocation of Government Offices in November as shown in Figure 4-2-1. It can be also noted in Table 4-2-1 that there is an increase in the BRT ridership during the weekends. The rate of BRT usage during the weekends over the weekdays has increased from 42.5% in April to 85.8% in January 2014.

Table 4-2-1. BRT ridership status in MAC (April, 2013 ~ January, 2014)

Month	Maximum Ridership in month (persons per day)	Accumulated Increase rate (%)	Population of MAC	Accumulated Increase rate (%)	Weekday		Weekend	
					Daily Average	Increase Rate (%)	Daily Average	Rate over weekday (%)
April	1,828	-	20,595	-	1,336	-	568	42.5
May	2,020	10.5	20,684	0.4	1,704	27.5	824	48.4
June	2,924	60.0	20,745	0.7	2,559	50.2	1,250	48.8
July	3,355	83.5	20,875	1.4	2,829	10.6	1,498	53.0
August	3,508	91.9	21,324	3.5	2,914	3.0	1,460	50.1

September	3,288	79.9	21,575	4.8	3,023	3.7	1,550	51.3
October	3,713	103.1	21,929	6.5	3,322	9.9	2,066	62.2
November	4,038	120.9	22,172	7.7	3,362	1.2	2,024	60.2
December	5,336	191.9	24,231	17.7	3,958	17.7	2,799	70.7
January	5,674	215.3	25,667	24.6	3,861	-2.4	3,313	85.8

(Population source: Sejong Special-Governing City. 2014. Population status, "About the Sejong City". http://www.sejong.go.kr/bbs/selectBoardList.do?boardId=PdsPop00)

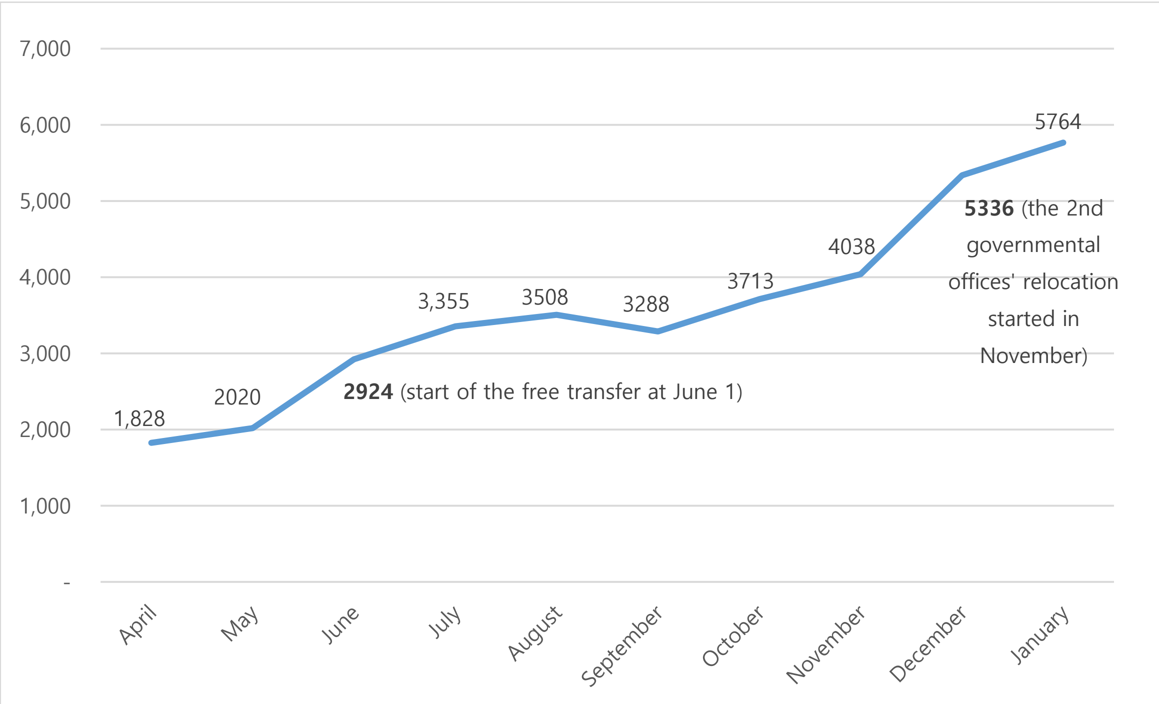


Figure 4-2-1. Maximum daily BRT ridership (persons/day) of a month in MAC (April, 2013 ~ January, 2014)

4.3. Comparative Analysis in the aspect of infrastructure and operation of BRT

When the BRT of MAC is compared with the other BRTs around the world as shown in Table 4-3-1, the BRT of MAC is outstanding in the aspect of network and ROW (Right of Way) of the running way. It has implemented 100% BRT-only lanes separated from other traffic on the entire length of the inner circular corridor and two metropolitan corridors. Most of the intersections are planned as over-bridge and underpass and the remaining intersections are planned to be equipped with BRT priority signal system.

However, considering the low ridership in the early stage of the development, the BRT system started its operation with the vehicles and stations which are similar in the appearance from the existing bus system. Although 90% of BRT users pay their fare by smart card, they pay their fare while getting on the bus because vehicles are not implemented with multiple doors and station with off-board fare collection system yet. Therefore, as the BRT ridership increases, the current vehicles and stations may result in the extra travel times.

In the aspect of the operation and administration, given the population and ridership demand in the early stage of city development, proper services are being provided in each operational element. However, according to the increase of ridership, more frequent and enlarged service is need and the oversight and management methods need to be prepared for efficient BRT service.

Table 4-3-1 Features of BRT in MAC (Currie and Delbosc, 2011 ; Galicia et al, 2009 ; Hensher and Golob, 2008 ; Hensher and Li, 2012 ; US GAO, 2012 ; Weinstock et al, 2011)

Infrastructure			
Type	**Elements**	**MAC***	**MAC explanation**
Network	catchment coverage	O	Circular BRT covers 65.6% of total MAC's area in walking access range.
	length of network	O	connecting near cities with 5 metropolitan lines
	network with other public transport	O	2 transfer terminal, 5 transfer center, connecting to metro, express railway station, (airport)
Running way	Bus lanes in central verge of the road	O	100%
	Physically separated right-of-way	O	100%
	transit preferential treatment systems at signalized intersections	O	100% implementation planned

Vehicle	articulated vehicle with multiple doors	X	
	Advanced automatic control systems(ITS)	X	
	Low-emission	O	CNG hybrid
	real-time information system (audio, video)	X	only audio information system
Station	level boarding	O	Level adjusted to low floor bus
	multiple docking bays and sub-stops	O	
	real-time information system	O	information kiosk in station
	wide and weather-protected shelter(with air conditioner, heater)	X	
	Stations occupy former road/median space (not sidewalk space)	O	median space in the road
	easy transfer (modal integration at station)	O	taxi stand, bicycle parking and share system, park and ride lot in part
	amenities	X	
Fare collection	pre-board fare collection	X	on-board fare collection
	integrated fare collection with other public transport	O	integrated with metro and bus
	smart card	O	over 90% of the BRT users
Branding	image and distinctive design	X	
Operation and Administration			
Type	Element		**references**
Operation	high frequency	Δ	10min on-peak, 15min off-pear
	speed	O	46.8km/h (31.2km, 40min)

	Reliability	Δ	Showing different travel time according to the number of people boarding
	service hours	O	05:00 AM~ 11:20 PM(18:20)
Administration	fare	O	$1.08
	feeder system	O	feeder bus
	quality control oversight from an independent agency	X	
	performance-based contracting for operators	X	
	enforcement of right of way	X	

*O: implemented or planned, **X**: not implemented or planned, Δ: unstable or imperfect in early operation stage
** Highlighted cells indicate elements not implemented in MAC's BRT systems

4.4. Summary of findings

MAC's BRT system is well organized in terms of the connection with other travel modes and surrounding regions. The BRT system is composed of inner circular line and metropolitan lines connecting nearby area's public transportation points such as the metro station, rail and high speed rail stations, and airport. Also, the system is equipped with transfer center and public bicycle system which can be connected with private automobile and bicycles and with free transfer system to adjacent city's bus and metro.

Also, the urban transit corridor was well planned as TOD. The 65.6% of population and 82.4% of land of commercial and business use are concentrated along the corridor within the 500m walking distance. Actually, from the survey result, it can be noted that 73% of the respondents walk to the BRT station and 47% reach the BRT station in 5 minutes, and overall, 74% reach the station in 10 minutes.

With the suitable environment for using BRT, due to the exclusive BRT running way contributing to the outstanding travel speed of 46.8 km/h in the section of 31.2 km, the ridership of BRT has sharply increased after eight months from the start of the operation. The percentage of daily ridership over the present population has increased from 8.9% (1,828/20,595) in April, 2013 to 22.5% (5,764/25,667) in January, 2014.

In addition, the response for the good right of way and environment for the BRT usage is verified by the survey responses from the question about the reason for using BRT. For this question, 37.2% of the respondents selected “convenient access to BRT station” followed by “less congested” which was selected by 29.0% of the respondents. Almost 70% of respondents chose the good urban environment to access to the BRT and good right-of-way of the BRT as the reason for using BRT.

However, despite of the good environments for using BRT and good infrastructure like the exclusive running way of BRT, the facilities such as vehicle, station, and fare collection system, and the operational and administrative system need to be improved to be comparable with the world best practices.

CHAPTER 5. IDENTIFICATIION OF ELEMENTS INFLUENCING SATISFACTION FOR THE BRT OF MAC

In Chapter 4, the comparison between MAC's BRT and the world's best practices showed the strong and weak points of MAC's BRT. But it is not clear whether or not the people using the BRT of MAC would agree with the result. Therefore, in this chapter, the comparison results are verified with the survey for finding the satisfactory and dissatisfactory elements of the BRT. Then the influence of each element for the overall satisfaction impression of the BRT was analyzed with a logistic regression analysis. In this chapter, the 91 responses that experienced MAC's BRT system were analyzed.

5.1. Survey result for satisfactory elements

Respondents for the survey about the most satisfied and dissatisfied element in the MAC's BRT answered that the most satisfying element is "travel speed" as shown in Table and Figure 5-1-1 and that the most dissatisfying element is "state-of-the-art image" as shown in Table and Figure 5-1-2. The same elements and the same order are presented in Tables and Figures 5-1-2 and 5-1-3 in order to show easy comparisons between the most satisfying and the most dissatisfying elements. These elements are consistent with the strong and weak elements shown from the comparison between the elements of BRT in MAC and the important elements distinguished in the existing research for being a successful BRT.

Table. 5-1-1. Most satisfying element in MAC's BRT (from Question 41 in Appendix A, the survey result are summarized in Table 4-2 of Appendix B)

	1st choice	2nd choice	Weighted number (%) (1st choice×2+2nd×1)
Travel speed	**30**	**24**	**84 (31.0%)**
Frequency	19	8	46 (17.0%)
Reliability	19	15	53 (19.6%)

Service hours	3	7	13 (4.8%)
State-of-the-art image	1	2	4 (1.5%)
Vehicle	4	3	11 (4.1%)
Station	3	9	15 (5.5%)
Boarding time including payment	2	3	7 (2.6%)
Fare level	0	0	0 (0.0%)
Transfer	7	9	23 (8.5%)
Information	0	3	3 (1.1%)
Accessibility	3	6	12 (4.4%)
Sum	91	89	271 (100%)

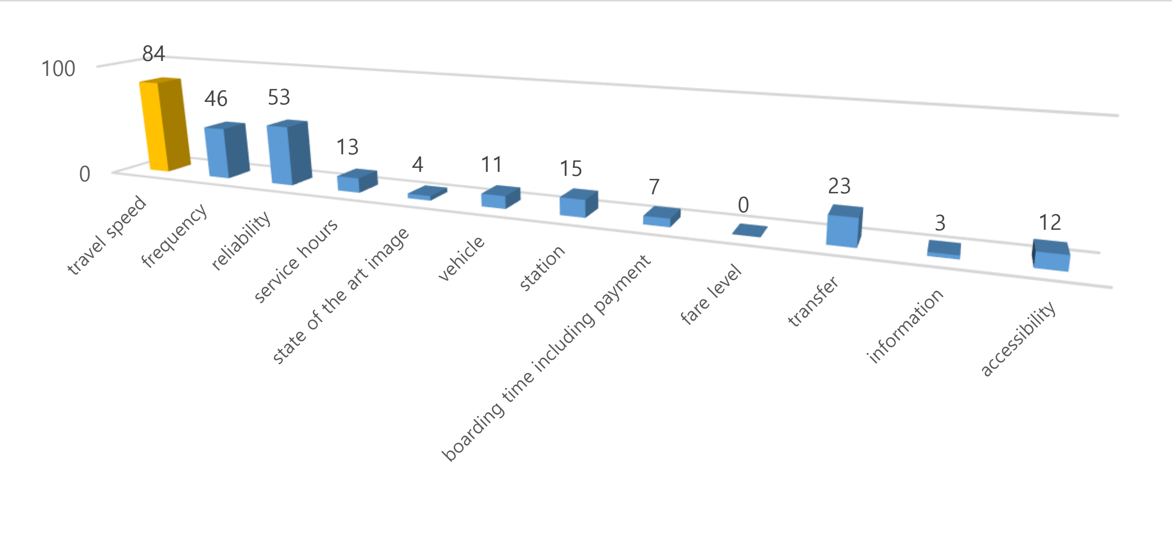


Figure 5-1-1. Most satisfying element in MAC's BRT (Unit: weighted numbers)

Table 5-1-2. Most dissatisfying element in MAC's BRT (from Question 42 in Appendix A, the survey result are summarized in Table 4-3 of Appendix B)

	1st choice	2nd choice	Weighted number (%) (1st choice×2+2nd×1)
Travel speed	3	1	7 (2.7%)
Frequency	11	7	29 (11.1%)
Reliability	0	2	2 (0.8%)
Service hours	3	5	11 (4.2%)
State-of-the-art image	**17**	**15**	**49 (18.8%)**
Vehicle	7	8	22 (8.4%)
Station	6	7	19 (7.3%)

Boarding time including payment	2	2	6 (2.3%)
Fare level	14	9	37 (14.2%)
Transfer	9	8	26 (10.0%)
Information	7	8	22 (8.4%)
Accessibility	9	13	31 (11.9%)
Sum	88	85	261 (100%)

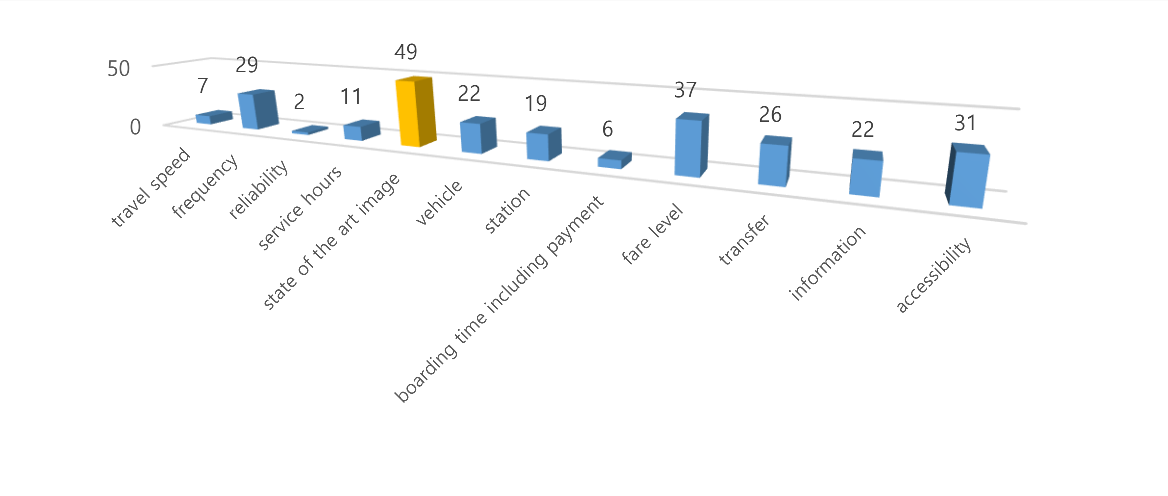


Figure 5-1-2. . Most dissatisfying element in MAC's BRT (Unit: weighted numbers)

5.2. Binary logistic regression analysis

Dependent variable is the overall satisfaction impression level for the BRT as shown in Table 5-2-1, and independent variables are the satisfaction level for each element of the BRT as shown 5-2-2. For this analysis, survey result for overall satisfaction impression level was transformed to binary form, "satisfied" or "not satisfied" as shown in Table 5-2-1.

Table 5-2-1. Dependent variable (from Question 28 in Appendix A, the survey result are summarized in Table 4 of Appendix B)

Overall satisfaction	sum	1. much dissatisfied.	2. dissatisfied	3. neutral	4. satisfied	5. very satisfied
Number	95	1	6	26	53	9
%	100	1.1	6.3	27.4	55.8	9.5
Binary value		0 : not satisfied, 33(34.7%)			1 : satisfied, 62(65.3%)	

Table 5-2-2. Independent variables (from Question 29~40 in Appendix A, the survey result are summarized in Table 4 and 4-1 of Appendix B)

Satisfaction level for	Min.	Max.	average	S.E.	order
Travel speed	2	5	3.81	0.829	2
Frequency	1	5	3.43	1.038	7
Reliability	2	5	3.92	0.846	1
Service hours	1	5	3.62	0.970	4
State-of-the-art image	1	5	3.21	0.966	12
Vehicle	1	5	3.31	0.839	10
Station	2	5	3.51	0.784	6
Boarding time including payment	2	5	3.68	0.762	3
Fare level	2	5	3.22	0.774	11
Transfer	2	5	3.54	0.796	5
Information	2	5	3.33	0.736	9
Accessibility	1	5	3.40	1.046	8

Table 5-2-3 presents the final results of the binary logit model using the overall satisfaction as the dependent variable and the Likert scale of each of the satisfaction elements as the value of independent variables. Only the satisfaction levels of travel time and boarding time are significant in explaining positive vs. negative overall satisfaction.

The logistic regression equation is

$$\ln\left(\frac{p}{1-p}\right) = 2.103 \times \begin{bmatrix} Satisfaction\ level \\ for\ \boldsymbol{travel\ speed} \end{bmatrix} + 1.381 \times \begin{bmatrix} Satisfacion\ level \\ for \\ \boldsymbol{boarding\ time} \\ including \\ payment \end{bmatrix} - 12.060$$

Where, p is the probability of being satisfied for MAC's BRT.

According to the equation, the coefficient β value of "Satisfaction level for travel speed" is 2.103 and the coefficient β value of "Satisfaction level for boarding time including payment." is 1.381. These values β are used for calibration of the binary logistic regression equation for predicting the relationship between the dependent variable and the independent variables

(UCLA, 2014).

Table 5-2-3. Result of binary logistic regression analysis for overall satisfaction impression

-2 Log likelihood	Cox & Snell R-square	Nagelkerke R- square
72.414	0.411	0.567

Section		Prediction		
		Overall satisfaction		Classification accuracy %
		0	1	
Overall satisfaction	0	24	9	72.7
	1	5	57	91.9
Total percentage				85.3

	β	S.E.	Wals	D.F.	p-value	Exp(β)
Boarding time including payment	1.381	0.509	7.363	1	0.007	3.979
Travel speed	2.103	0.500	17.706	1	0.000	8.191
Constant	-12.060	2.716	19.722	1	0.000	0.000

5.3. Summary of findings

According to the result of the survey for the satisfactory elements in MAC's BRT, the most satisfying element is "Travel speed" and the most dissatisfying element is "State-of-the-art image" which is consistent with the result of the comparison between the BRT of MAC and the world's renowned BRTs in Chapter 4.

However, the logistic regression analysis result shows that only the travel time related elements such as "Satisfaction level for travel speed" and "Satisfaction level for boarding time" have a relationship with the "Overall satisfaction impression for the BRT" in a significant level.

CHAPTER 6. IDENTIFICATION OF ELEMENTS INFLUENCING BRT RIDERSHIP IN MAC

From the study result of Chapter 5, it is clear that travel speed and time are very important elements for the satisfaction of the BRT users. Therefore, in this Chapter, questions such as “which element is influential for BRT usage frequency?” and “is “travel speed or travel time” still influential on the BRT usage frequency as well as satisfaction?” are considered.

6.1. Current BRT usage frequency

By the time of the survey, about 6 months after start of the BRT operation, the frequency of BRT usage was very low. 41.7% of the respondents had never used BRT, and 28.2% of the respondents had used the BRT irregularly, less than 1 day per week. Respondents who use BRT at least 1 day per week are just 30.1%. Only 13.5% of the respondents use BRT regularly in the frequency of over 3 days per week.

6.2. Preference survey for elements to increase the BRT using frequency

In the survey question like “Which element is most important to increase your frequency of BRT usage?”, travel time related elements such as “Faster travel time” and “More frequent arrivals” had high response levels as shown in Figure 6-2-1. “Less expensive” and “Improved accessibility” were also among frequent responses. However, “Improved image” and elements related to advanced public transit facilities such as “Weather-protected station”, “Higher capacity vehicle”, and “Off-board fare collection system” did not attract many responses.

Respondents selected “State-of-the-art image” as the most dissatisfying element of the BRT of MAC but they thought that the image of the BRT is irrelevant to their BRT usage frequency. The residents of MAC show the tendency of preferring the practical elements like the travel time, expense and accessibility to the elements related to state-of-the-art image of new advanced transit system for increasing their BRT use.

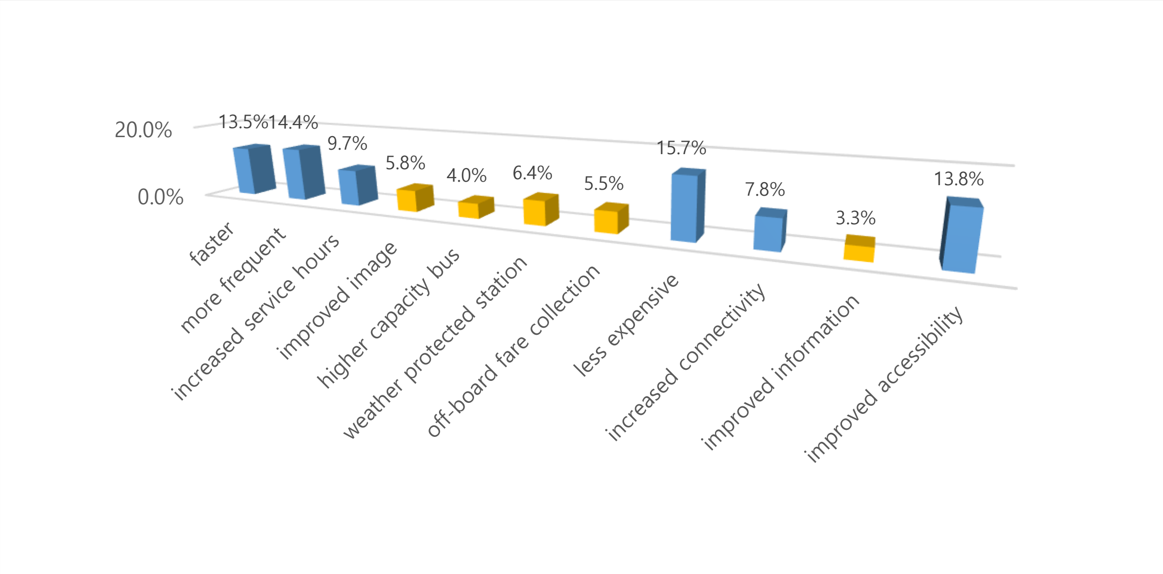


Figure 6-2-1. Most influential element for increasing BRT use

6.3. Binary logistic regression analysis

Independent and dependent variables

MAC's BRT has a very good right of way for BRT and shows good performance in the travel speed as shown in Chapter 4. Moreover, the travel speed of BRT is the most satisfied element for the residents of MAC and the most influential element for determining the overall satisfying impression on MAC's BRT as mentioned in the analysis result of Chapter 5. In the stated preference survey of this chapter, time-related improvements like "faster travel time" and "more frequent arrivals" were chosen as the important improvements needed for an increase in BRT ridership.

As the traffic increases in the future, travel speed will be decreased in the vehicular lanes but not in the BRT lane of the circular main transit corridor. While the travel time for using the

BRT lane may not change much, the travel time of using the other lanes may increase with increased traffic.

Therefore, to see the impact on the increase of the BRT ridership resulted from the urban structure in the inner circular BRT transit corridor which has a low capacity for private cars and has high-concentration along the narrow corridor, the ratio of the travel time between each cases of using a private car and of using the BRT (total travel time when use private car/total travel time when use BRT) is tried as the independent variable with other variables related to travel behaviors and socio-economic features.

The total respondents who have used both the private car and BRT was only 41 out 163 respondents. To produce an effective logistic regression analysis result with small sample numbers in each category, the dependent variable needs to be set as binary variable, "Whether on not being frequent BRT user who uses BRT 3days or more per week" as shown in Table 6-3-1.

Table 6-3-1. Dependent variable (frequent BRT user who uses BRT 3days or more per week)

BRT using frequency	sum	below 1day per week	1day per week	2days per week	3days per week	4days per week	5days per week	6days per week
Number	41	20	9	5	2	2	2	1
%	100%	48.8%	22.0%	12.2%	4.9%	4.9%	4.9%	2.4%
Binary value		**0: not frequent user, 34 (82.9%)**			**1: frequent BRT user, 7 (17.1%)**			

41 sample group is for the people who have used both the travel time data of the car and BRT, and 163 sample group is for the whole sample surveyed. Because the 41 sample group is used for analysis instead of the whole sample, the features in the 41 sample group should be consistent with the whole sample group. The data of these two sample group show similar

average values and standard deviation in most of the socio-economic variables as shown in the following Table 6-3-2.

Table 6-3-2. Comparison between 41 sample group and 163 sample group

		41 sample group		163 sample group	
		Average	Standard deviation	Average	Standard deviation
age	20s ~ 60s (2~6)	3.49	0.870	3.37	0.968
gender	0: female, 1: male	0.29	0.461	0.36	0.480
Education completed	1: below high school 2: high school 3: junior college 4: college 5: graduate school	3.44	0.867	3.48	0.919
occupation	1: students 2: government employee 3: public sector 4: private sector 5: self-employed 6: other	5.10	1.609	4.48	1.857
marriage	0 : single, 1: married	0.78	0.419	0.77	0.420
Annual income	1: ~ 20million won 2: 20~40 3: 40~60 4: 60~80 5: over 80million won	2.98	1.060	2.81	1.010
Household size	1: 1 person ~ 6: 6 persons and over	3.61	0.891	3.53	0.983
Car ownership	1: none 2: 1 car 3 : 2 cars 4: 3 cars and over	2.24	0.663	2.36	0.674

Binary logistic regression analysis result

Among the independent variables used from the socio-economic survey data, trip behavior data, and BRT using data, the ratio of the travel time in each case of using a private car and of using BRT and trip frequency have β values in an effectively significant level.

From the following binary logistic regression analysis result of Table 6-3-3, the binary logistic regression equation is

$$\ln\left(\frac{p}{1-p}\right) = 9.563 \times [Travel\ time\ ratio] + 2.865 \times [Trip\ frequency] - 15.370$$

Where, p is the probability of being a frequent BRT users of 3 days or more per week.

This equation shows a high sensitivity in the value of BRT usage with respect to the change of "travel time ratio". The probability of being a frequent BRT users 3days or more per week is influenced by the number of "trip frequency" in the effective significance level.

Table 6-3-3. Binary logistic regression analysis result

-2 Log likelihood	Cox & Snell R-square	Nagelkerke R- square
11.343	0.471	0.787

Section		Prediction		
		Overall satisfaction		Classification accuracy %
		0	1	
Overall satisfaction	0	32	2	94.1
	1	1	6	85.7
Total percentage				92.7

	β	S.E,	Wals	D.F.	p-value	Exp(β)
TT ratio	9.563	4.756	4.042	1	0.044	14226.032
Trip frequency	2.865	1.353	4.483	1	0.034	17.547
constant	-15.370	7.274	4.465	1	0.035	0.000

And this equation can be transformed to like followings

$$\frac{p}{(1-p)} = e^{(9.563 \times Travel\ time\ ratio\ +\ 2.865\ \times Trip\ frequency\ -\ 15.370)}$$

$$p = \frac{e^{(9.563 \times Travel\ time\ ratio\ +\ 2.865\ \times Trip\ frequency\ -\ 15.370)}}{(1 + e^{(9.563 \times Travel\ time\ ratio\ +\ 2.865\ \times Trip\ frequency\ -\ 15.370)})}$$

From this equation, when the variable “Trip frequency” is fixed as 1, 3, and 5 times per week, three different curves between “Probability being frequent BRT user” and “Travel time ratio” are drawn as shown in the following Figure 6-3-1.

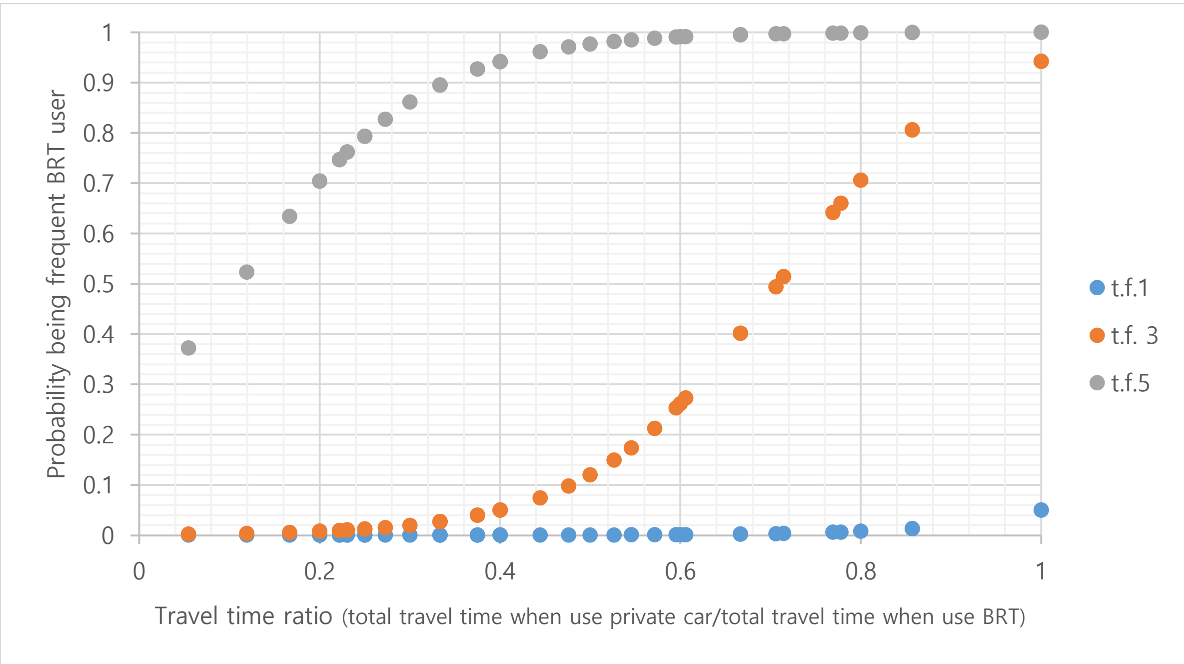


Figure 6-3-1. Probability to be frequent BRT user by “Travel time ratio” and “Trip frequency per week (t.f.)”

Among these three line, the 3 times per week frequency shown as the orange colored line is close to the average trip frequency 3.52 of the survey result. In the orange colored line, the probability to be the frequent BRT user who uses BRT 3 days or more per week is 12% at the travel time ratio of 0.5 which is similar to the present travel time ratio of 0.47 from the survey result. This probability of 12% is also similar to the present percentage of using BRT in the frequency of 3 days or more per week, 13.5%. The probability in increasing the BRT usage up to the frequency of 3 days or more per week has a very high sensitivity with respect to the travel time ratio, especially in the section of 0.5 and 0.8 where the probability increases nearly 6 times from 12% to 71%. This infers that if the travel time of car increases compared to the travel time of BRT, the ridership of BRT will increase sharply after the travel time using a car is more than half of the travel time using the BRT.

6.4. Summary of findings

In the revealed preference survey for an important element on increasing their BRT usage frequency, the residents of MAC showed the tendency of preferring the practical elements such as travel time, expense and accessibility to the elements related to state-of-the-art image of new advanced transit system.

The result of the binary logistic regression analysis shows the high sensitivity of BRT ridership increase with respect to the travel time ratio which means that the increase of travel time using a private car in the main circular transit corridor can increase the BRT ridership greatly. In other words, if the travel speed of BRT decrease, the ridership of private car may increase sharply.

CHAPTER 7. PREDICTION OF FUTURE MODE SHARE AND TRAVEL TIME

In Chapter 6, the close relationship between the travel time ratio and the increase of BRT ridership was verified through the binary logistic regression analysis. In this chapter, the future traffic condition is predicted by using the relationship between the travel time ratio and BRT ridership. Considering the fact that the roads in MAC were designed by the policy goal of controlling the mode share of car under 30%, the prediction of the future mode share of car can help the policy maker to determine the direction for the BRT improvement.

7.1. Relationship between the mode share and travel time ratio

The mode shares for each travel mode are needed in order to predict the future traffic condition. As shown in the following Table 7-1-1, which compares the frequency of BRT use with primary travel mode choice, 90% of the people who use BRT in the frequency of 3days or more per week chose BRT as their primary travel mode. However, 14.7% of the total respondents selected BRT as their primary travel mode in spite of their low usage, under 3 days per week.

Table 7-1-1. Relationship between BRT using frequency and primary travel mode choice

BRT using frequency	car	BRT	c. bus	g. bus	taxi	walk	other	Total
none	52	1	2	7	2	4		68
below 1 day per week	29	8	2	2		4	1	46
1 day per week	5	6						11
2 days per week	3	9	4					16
3 days per week	1	8		1				10
4 days per week		4						4
5 days per week		3						3
6 days per week		2						2
7 days per week		3						3
Total (mode share)	**90 (55.2%)**	**44 (27%)**	**8 (4.9%)**	**10 (6.1%)**	**2 (1.2%)**	**8 (4.9%)**	**1 (0.6%)**	**163**

From these findings, the following relationships are derived.

Mode share of BRT (%) = 0.9 * Probability using BRT 3days or over per week + 14.7

Mode share of car (%) = 100 – BRT's mode share – 17.8 (with the assumption that the other travel modes except for BRT and car stay in the current mode share, 17.8%)

In addition, if the graph in Figure 6-3-1 is utilized, the relationship between the travel time ratio of car and BRT and mode share can be induced as shown in Table 7-1-2.

Table 7-1-2. Expected mode share according to Travel time ratio

Travel time ratio	0.5	0.6	0.7	0.8	0.9
P(BRT use 3 days and over) (by orange line in Figure 6-3-1)	12.0%	27.0%	48.0%	70.0%	87.00%
0.9×P(BRT use 3 days and over)	10.8%	24.3%	43.2%	63.0%	78.3%
Expected BRT mode share : 0.9P+14.7%(BRT users' portion who use BRT in the frequency under 3 days per week)	25.5%	39.0%	57.9%	77.7%	-
expected private car's share (100% - BRT – other modes (17.8%)*)	56.7%	43.2%	24.3%	-	-

* Assumption : mode share of other modes except for private car and BRT is constant with present **17.8%**

7.2. Prediction of future travel time and mode share

A simulation program Visum is used to predict the future travel speed of cars in the main transit corridor. The Origin/Destination (O/D) and network data for the simulation were built with the base data of 2010 National Transportation Data Base Construction Research of the Korea Transport Institute (KOTI, 2012).

However, travel time obtained from Visum is the travel time in the main transit corridor without the time that takes to approach to the car and leave the car to go to the destination. Several assumptions are needed to get the total travel time as shown in the following Table 7-2-1.

First, the total travel time using BRT is comprised of the travel time from home to station, waiting time in station, travel time on board, and travel time from station to destination. Travel time from and to the station can use the survey result for BRT usage. Residents in First town near the main transit corridor spend an average 10.48 minutes to go to the BRT station. Considering the concentrated development along the main transit corridor, this 10.48 minutes can be applied in both the travel time from and to the station. According to Public Transportation System Establishment (MACCA, 2011.9.), the planned headways in peak time are 1.5minutes in 2020 and 1.25 minutes in 2030 which are so ideal. Therefore, by considering the minimum headway, 4 minutes of BRT of Seoul in South Korea (TAGO, 2014), the waiting times are assumed as 3 minutes in 2020 and 2 minutes in 2030. Although the present maximum travel speed of BRT in the section of 31.2 km is 47 km/hour (Lee, 2013), the planned travel time on the main transit corridor is assumed as 20 minutes according to MAC's Development Plan (MACCA, 2006) with the consideration that the increased number of station and increase boarding time in station resulted from the increased passengers.

Second, the total travel time of using a private car consists of the traveling time to the car in the parking lot, travel time on board, parking time, and travel time from car to destination after parking. The travel time to and from car and parking time are assumed with a research performed in Korea (Kim et al, 2003).

According to Kim's research, the average waiting time for parking is 3minutes and the maximum is 25minutes. Average walking time to the destination from parking lot is 6 minutes which can be utilized to assume the travel time to parking lot.

Table 7-2-1. Assumption of travel time in 2020, 2030 (in the distance of 10km)

	time (min)	**2020**	**2030**
BRT	Access time to station	10.48	10.48
	Waiting time	3	2
	In-vehicle time	20.00	20.00
	Travel time from station	10.48	10.48
	Total travel time	43.96	42.96
private car	Access time to car	6	6
	In-vehicle time	-	-
	Parking time	3	3
	Travel time from car	6	6
	Total travel time	-	-

Visum can not produce the future travel speed without mode shares. Therefore, the iterative method is applied for finding the converged values of mode share and travel speed by using the relationship between the travel time and mode share. If an initial guess of mode share in 2020 and 2030 is used, like the first column of Tables 7-2-2 and 7-2-3, Visum can produce the travel speed of a car in the main transit corridor according to the input mode share. The travel speed produced by the program does not show a big difference with travel speed predictions of Traffic Impact Assessment of MAC (KLC, 2007) which are 40.96km/h in 2020 and 39.52 km/h in 2030 in the car mode share of 30%.

With a predicted car travel speed in 2020 and 2030, the car travel time and the ratio of total travel time in each case between using a car and BRT can be calculated by using Table 7-2-1 while assuming the elements of total travel time as shown in the 3rd and 4th column of Tables 7-2-2 and 7-2-3.

Table 7-2-2. In-vehicle travel time of car and Travel time ratio in 2020 (which can be input into the blank of table 7-2-1)

Input value of car mode share	**Travel speed** (km/h) of car on the main transit corridor			**Travel time** (min) on board of private car in the section of 10.5km main transit corridor including approaching 0.5km	**Travel time ratio**
	Clock wise	Count-clock wise	Average		
26.50%	50.18	48.90	49.54	12.72	0.63
27.20%	49.03	47.78	48.41	13.02	0.64
28.34%	48.22	48.28	48.25	13.06	0.64
30.00%	46.81	47.22	47.02	13.40	0.65
32.00%	45.61	45.32	45.47	13.86	0.66
32.30%	45.25	44.62	44.94	14.02	0.66
32.40%	45.31	44.52	44.92	14.03	0.66
32.43%	45.23	44.30	44.77	14.07	0.66
32.44%	**45.27**	**44.19**	**44.73**	**14.08**	**0.66**
32.45%	45.22	43.17	44.20	14.26	0.67
32.50%	43.65	44.56	44.11	14.28	0.67
35.55%	41.89	42.42	42.16	14.94	0.68
37.07%	40.16	42.10	41.13	15.32	0.69
37.20%	39.96	42.20	41.08	15.34	0.69
38.50%	40.31	42.74	41.53	15.17	0.69

Table 7-2-3. In-vehicle travel time of car and Travel time ratio in 2030 (which can be input the blank of table 7-2-1)

Input value of car mode share	**Travel speed (km/h)** of car on the main transit corridor			**Travel time (min)** on board of private car in the section of 10.5km main transit corridor including approaching 0.5km	**Travel time ratio**
	Clock wise	Count-clock wise	Average		
21.40%	53.70	52.73	53.22	11.84	0.6247
24.20%	49.03	48.07	48.55	12.98	0.6512
25.80%	48.00	47.06	47.53	13.25	0.6577
26.60%	46.79	46.20	46.50	13.55	0.6646

28.00%	45.12	45.47	45.30	13.91	0.6729
28.50%	44.61	44.98	44.80	14.06	0.6765
29.00%	45.27	44.18	44.73	14.09	0.6771
29.05%	**44.00**	**45.33**	**44.67**	**14.11**	**0.6775**
29.06%	43.60	44.55	44.08	14.29	0.6819
29.10%	43.77	45.26	44.52	14.15	0.6786
29.30%	43.90	43.84	43.87	14.36	0.6834
29.50%	43.53	43.54	43.54	14.47	0.6860
30.00%	43.61	42.66	43.14	14.61	0.6891
31.80%	41.99	43.35	42.67	14.76	0.6928
33.20%	41.74	41.76	41.75	15.09	0.7004

Then, the future mode share can be calculated with the travel time ratio by using Table 7-1-1 and 7-1-2 which show the relationship between the probability of using BRT 3 days or more per week and the mode share of BRT and private car. By iterating the process until the input mode share of the private car become close to the output mode share of the private car, the converged mode share of the private car and the matched travel time ratio are earned as shown in the following Table 7-2-4, 5 and Figures 7-2-1, 2. The predicted modes share of private car is 32.44% in 2020 and 29.05% in 2030 while the travel time ratio is 0.6616 and 0.6775.

Table 7-2-4. Prediction of travel time ratio and mode share in 2020

Input value of car mode share	TT ratio	Probability of using BRT 3 days and over	Output mode share		Difference between input and output
			BRT	Private car	
26.50%	0.6305	32.18%	43.66%	38.54%	12.04%
27.20%	0.6373	33.61%	44.95%	37.25%	10.05%
28.34%	0.6382	33.82%	45.13%	37.07%	8.73%
30.00%	0.6460	35.51%	46.65%	35.55%	5.55%
32.00%	0.6564	37.81%	48.73%	33.47%	1.47%
32.30%	0.6602	38.65%	49.49%	32.71%	0.41%
32.40%	0.6603	38.68%	49.52%	32.68%	0.28%
32.43%	0.6614	38.93%	49.73%	32.47%	0.04%

32.44%	**0.6616**	**38.98%**	**49.79%**	**32.41%**	**-0.03%**
32.45%	0.6655	39.87%	50.58%	31.62%	-0.83%
32.50%	0.6662	40.02%	50.72%	31.48%	-1.02%
35.55%	0.6812	43.52%	53.86%	28.34%	-7.21%
37.07%	0.6897	45.52%	55.66%	26.54%	-10.53%
37.20%	0.6901	45.62%	55.76%	26.44%	-10.76%
38.50%	0.6863	44.73%	54.96%	27.24%	-11.26%

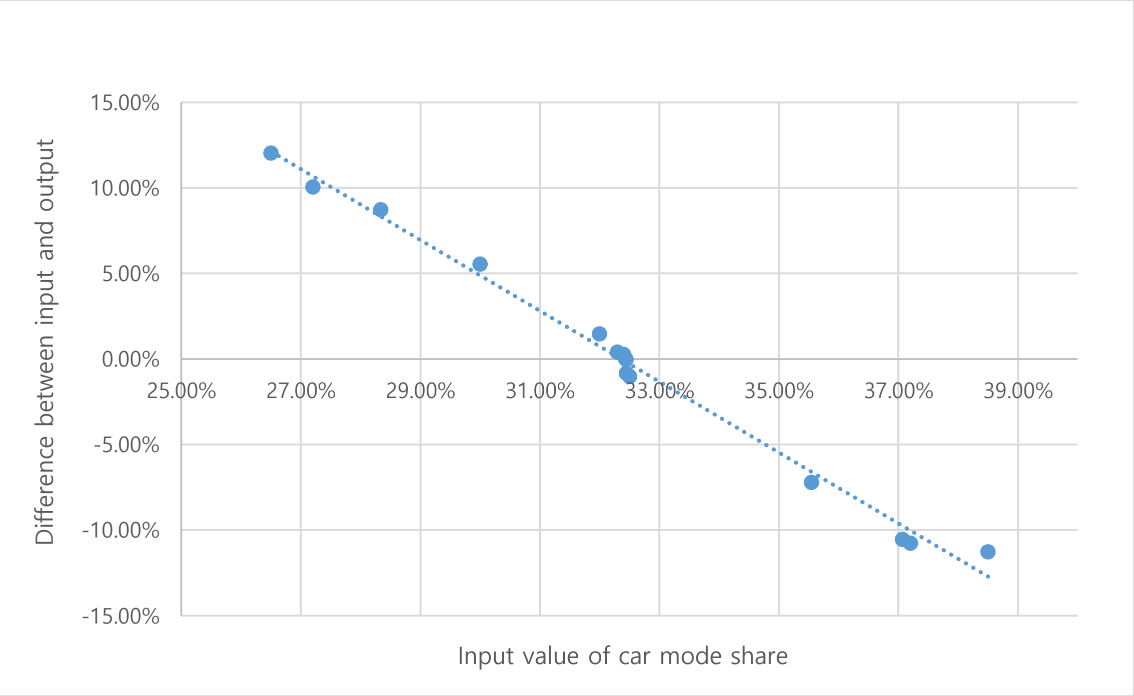


Figure 7-2-1. Finding of the converged mode share of private car in 2020

Table 7-2-5. Prediction of travel time ratio and mode share in 2030

Input value of car mode share	TT ratio	Probability of using BRT 3 days and over	Output mode share		Difference between input and output
			BRT	Private car	
21.40%	0.6247	30.99%	42.59%	39.61%	18.21%
24.20%	0.6512	36.65%	47.68%	34.52%	10.32%
25.80%	0.6577	38.10%	48.99%	33.21%	7.41%
26.60%	0.6646	39.66%	50.39%	31.81%	5.21%

28.00%	0.6729	41.59%	52.13%	30.07%	2.07%
28.50%	0.6765	42.43%	52.88%	29.32%	0.82%
29.00%	0.6771	42.55%	52.99%	29.21%	0.21%
29.05%	**0.6775**	**42.65%**	**53.08%**	**29.12%**	**0.07%**
29.06%	0.6819	43.68%	54.01%	28.19%	-0.87%
29.30%	0.6834	44.05%	54.34%	27.86%	-1.44%
29.50%	0.6860	44.65%	54.89%	27.31%	-2.19%
30.00%	0.6891	45.39%	55.55%	26.65%	-3.35%
31.80%	0.6928	46.27%	56.35%	25.85%	-5.95%
33.20%	0.7004	48.08%	57.97%	24.23%	-8.97%

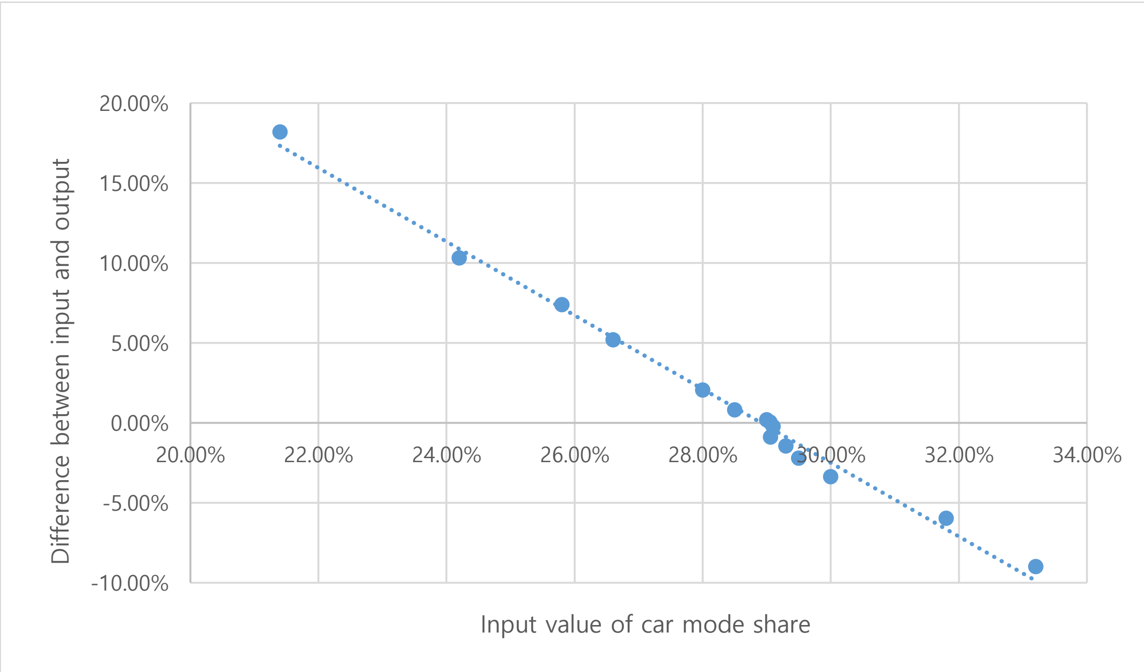


Figure 7-2-2. Finding of the converged mode share of private car in 2030

7.3. Summary of findings

In this chapter, the future travel speed in the transit corridor and mode share are predicted by using the relationship between the mode share and travel time ratio with the Visum program. The predicted modes share of private car is 32.44% in 2020 and 29.05% in 2030 which is under the target mode share of 30% in 2030.

According to Table 7-1-2, the mode share of private car increase in the ratio of 18.9% by 0.1 change of the travel time ratio between 0.6 and 0.7. With this level of high sensitivity of the BRT ridership to travel time ratio, it is expected that target mode share of under 30% will last because there is no other public transit to replace the BRT in the circular transit corridor along which is highly concentrated with houses and jobs. However, because of the high sensitivity between mode share change and travel time, there will be a big mode change from BRT to private car resulted from the decrease in the travel speed of BRT.

CHAPTER 8. CONCLUSION AND RECOMMENDATION

8.1. Conclusions

MAC's BRT system is well planned in terms of connectivity with other region and other travel modes. Also, it has a very good right of way which contributes to the current high travel speed of 46.8km/h in the section of 31.2km. However, when it is compared with the world renowned BRTs, the facilities such as vehicle, station, and fare collection system need to be improved.

Residents of MAC also support the comparison result with other BRTs. They responded that the BRT's "travel speed" is the most satisfying element but it lacks of the "State-of-the-art image" (e.g., vehicle with multiple doors and stations with better amenities and new fare collection system). However, their BRT ridership is highly sensitive towards the difference in the travel time between using BRT and private car but not towards the "State-of-the-art image."

The predicted mode share of private car is 32.4% in 2020 and 29.1% in 2030, which is under the target mode share of 30% in 2030. It is likely that the target mode share of under 30% would be achieved due to the high sensitivity of BRT ridership towards the travel time and the fact that there is no other public transit to replace the BRT in the circular transit corridor that is highly concentrated with houses and jobs.

However, when the BRT's travel time increases due to more users needing additional time to onboard and alight, the travel time of cars on the corridor may also increase due to increased number of cars by mode shift from the BRT to cars. Therefore, for a good traffic flow in both BRT and other lanes of the inner circular transit corridor, the traveling time of BRT should continue to improve in order to increase of ridership.

8.2. Recommendations for BRT in MAC

Among the elements of travel time of BRT, the elements which can be reduced by the operator are “waiting time in station” by shortening headway of BRT and “dwelling time of a vehicle in stations” by shortening the boarding and alighting time. Dwelling time at a station can be shortened by improving the weak features compared to other BRTs. High capacity articulated bus with multiple doors and alternative fare collection system such as off-board fare collection and on-board fare inspection can contribute to the travel time saving by reducing boarding and alighting times. In addition, specialized vehicles, attractive stations with amenities, and efficient fare collection system would result in an approximately 40% gain in base ridership on top of the gains from travel time and service frequency improvements by contributing to customers’ perception of BRT as a high-quality transit service (Kittelson & Associates et al, 2007).

Therefore, the improvements in vehicle, station, and fare collection system should be implemented to prevent the decrease of travel speed of BRT. It is noted that these would help addressing the dissatisfaction for the “state-of-the-art image” of MAC’s BRT.

8.3. Recommendations for future research

This thesis has identified that the differences in travel times between BRT and other vehicles was the most influential element in determining the BRT ridership in MAC, a BRT based transit-oriented city. However, the result was based on a survey conducted in early stage of the development with a small survey sample. So, a research with a bigger survey sample should be followed up to verify if the result would be effective in the future and if such systems should be used for similar TOD cities.

Additionally, MAC was planned to provide a good environment towards walking and bicycling and to implement a bike share system, but the mode share of walking and bicycling was found to be relatively low because of on-going construction in the majority of the area. MAC expects the mode share of walking and bicycling to reach near 30% by 2030. As the population increases and urban development continues, it is expected that the use of non-motorized travel modes will increase. Therefore, different analysis methods such as nested logit model and multinomial logit model need to be applied to consider the impact of non-motorized modes such as walking and bicycling in the corridor.

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Appendix A: Survey Questionnaire

* This questionnaire was designed by Hyung Wook Choi for thesis research. Most of responses were gathered through in-person survey in First town in Sejong City from late October to early November, 2013. The results are presented in Appendix B.

1. Personal information

Q1.age?

below 20s( ), 20s ( ), 30s ( ), 40s ( ), 50s ( ), 60s ( ), 70s and over( )

Q2.gender : male ( ), female ( )

Q3.education completed : below high school ( ), high school ( ), junior college( ), college ( ), graduate school ( )

Q4.occupation : student ( ), government employee ( ), public sector ( ), private sector ( ), self-employed ( ), other ( )

Q5.Marriage status : single or divorced ( ), married ( )

Q6.annual household income

20million won ( ), 20~40 ( ), 40~60 ( ), 60 ~80( ), over 80 ( )

Q7.household size : 1 ( ), 2 ( ), 3 ( ), 4 ( ), 5 ( ), 6 or more ( )

Q8.household car ownership : 0( ), 1 ( ), 2( ), 3 or more( )

Q9.residential area : first town ( ) stage, ( )complex

Q10.type of resident? own ( ), charter( ), monthly rental ( ), mixed type of charter and monthly rental ( ), release ( )

Q11.place of employment or school?

In MAC( ), Sejong (except MAC)( ), Daejeon( ), Chungnam( ), Chungbuk ( ), Capital area ( ), other ( )

2. Trip information

Q12. Main purpose of your general trip?

commute ( ), school ( ), business ( ), shopping ( ), eating out ( ), recreation ( ), hospital ( ), other ( )

Q13. Primary mode for trip?

Private car( ), BRT( ), commuting bus ( ), general bus ( ), taxi ( ), walking( ), bicycle ( ), other ( )

Q14. How many days do you use in a week for the purpose identified in Q12?

1day( ), 2days( ), 3 days ( ), 4 days ( ), 5 days ( ), 6 days ( ), 7 days ( )

Q15. With mode selected in Q13, your total travel time for the trip you selected in Q12? ( ) min

Q16. Your available mode except for the mode that you selected in Q13?

Private car( ), BRT( ), commuting bus ( ), general bus ( ), taxi ( ), walking( ), bicycle ( ), other ( )

Q17. Travel time when you use the mode selected in Q16? ( ) min

3. BRT using information

Q18. How often do you use BRT?

None ( ), below 1 day ( ), 1day ( ), 2 ( ), 3 ( ), 4 ( ), 5 ( ), 6 ( ), 7 days ( )

※ "if you select "none" skip Q19~42 and go to Q43

Q19.primary purpose of using BRT?

commute ( ), school ( ), business ( ), shopping ( ), eating out ( ), recreation ( ), hospital ( ), other ( )

Q20.your primary mode before moving to MAC?

Private car ( ), metro ( ), commuting bus ( ), general bus ( ), taxi ( ), walking( ), bicycle ( ), other ( )

(Answer Q21 through Q26 for your trip your.)

Q21. Mode and travel time to Departure BRT station	walking( ), bicycle( ), bus( ), taxi( ), private vehicle( ), other( )	( ) min
Q22. Departure BRT station	( ) station	
Q23. Waiting time in station		( ) min
Q24. Travel time on board		( ) min
Q25. Arrival BRT station	( ) station	
Q26. Mode and travel time from arrival BRT station	walking( ), bicycle( ), bus( ), taxi( ), private vehicle( ), other( )	( ) min

Q27. Why do you choose BRT over the other modes? (select all applied)

convenient location of a BRT stations ( )
inconvenient parking near the destination( )
less congested ( )
less expensive ( )
for health and environment ( )
others ( )

4. BRT satisfaction

(answer Q28 through Q40 for your satisfaction when you use BRT)	Very satisfied	satisfied	neutral	dissatisfied	Very dissatisfied
Q28. Overall impression 4-1					
Q29. Travel speed (total travel time)4-2					
Q30. Frequency (headway) 4-3					
Q31. Reliability 4-4					
Q32. Service hours (5am~11pm) 4-5					
Q33. Image 4-6					
Q34. Ride comfort during peak hours 4-7					
Q35. Station comfort 4-8					
Q36. Boarding time including fare collection system 4-9					
Q37. Fare level 4-10					
Q38. Transfer to other modes 4-11					
Q39. Information system 4-12					
Q40. Access to BRT station 4-13					

Q41. Which do you think the most satisfied one is among 29-Q40?

(1st : , 2nd :)

Q42. Which do you think the least satisfied one is among Q29-Q40 ?

(1st : , 2nd :)

5. BRT improvement

(Answer Q43 through Q53 for your intention to start using BRT if you haven't use BRT, and to increase your using frequency if you are BRT user)	Very important	important	neutral	unimportant	much unimportant
Q43. Faster 5-1					
Q44. More frequent 5-2					
Q45. Increased service hours 5-3					
Q46. Improved image (design, brand) 5-4					
Q47. Higher capacity bus (articulated) 5-5					
Q48. Weather protected station 5-6					
Q49. Off-board fare collection 5-7					
Q50. Less expensive 5-8					
Q51. Increased connectivity to other modes 5-9					
Q52. Improved information system 5-10					
Q53. Improved accessibility to BRT station 5-11					

Q54. Which do think the most important thing is among Q43-Q53?

(1st : , 2nd :)

Q55. What is your response for the improvement suggestions?

in one month, start and improve BRT use ( )

gradually start and improve BRT use ( )

regardless of improvement, don't use BRT ( )

Thank you!

Appendix B. Survey Result Summary

* This survey results were used as base data in the thesis and most of the data were tried as independent variables in binary logistic regression analyses in Ch. 5 and Ch. 6.

Table 1. Socio-economic data

		number	%
gender	male	58	35.6
	female	105	64.4
stage	1st	97	59.5
	2nd	66	40.5
age	20s	33	20.2
	30s	57	35.0
	40s	57	35.0
	50s	12	7.4
	60s	4	2.5
job	student	13	8.0
	government	32	19.6
	public sector	5	3.1
	private sector	7	4.3
	self-employed	26	16.0
	other	80	49.1
income	20mil. Won	15	9.2
	20~40	45	27.6
	40~60	70	42.9
	60~80	22	13.5
	over 80	11	6.7
marriage	single	58	22.7
	married	105	77.3
education completed	below high school	1	0.6
	high school	35	21.5
	junior college	22	13.5
	college	95	58.3
	graduate school	10	6.1
household size	1	7	4.3
	2	16	9.8
	3	43	26.4
	4	80	49.1
	5	15	9.2
	6 or more	2	1.2
car ownership	0	9	5.5

	1	95	58.3
	2	50	30.7
	3 or more	9	5.5
type of residence	own	90	55.2
	charter	43	26.4
	monthly rent	10	6.1
	mixed	3	1.8
	release	17	10.4
place of employment	in MAC	107	65.6
	Sejong	10	6.1
	Daejeon	23	14.1
	Chungnam	9	5.5
	Chungbuk	1	0.6
	Capital region	1	0.6
	other	12	7.4

Table 2. Travel behavior data

		number	%
trip purpose	commute	56	34.4
	school	8	4.9
	business	22	13.5
	shopping	27	16.6
	eating out	1	0.6
	recreation	21	12.9
	hospital	4	2.5
	other	24	14.7
primary mode for trip	private car	90	55.2
	BRT	44	27
	commute bus	8	4.9
	general bus	10	6.1
	taxi	2	1.2
	bicycle	0	0
	walking	8	4.9
	other	1	0.6
trip frequency	1 day/week	33	21.0
	2days	33	21.0
	3days	20	12.7
	4days	14	8.9
	5days	26	16.6

	6days	10	6.4
	7days	21	13.4
travel time with primary mode	~10min	32	20.4
	11~20	61	38.9
	21~30	34	21.7
	31~40	14	8.9
	41~50	5	3.2
	51~60	7	4.5
	over 60	4	2.5
	no response	6	
second mode for trip	private car	44	27.2
	BRT	40	24.7
	commute bus	7	4.3
	general bus	27	16.7
	taxi	26	16.0
	bicycle	9	5.6
	walking	5	3.1
	other	4	2.5
	no response	1	
travel time with primary mode	~10min	32	20.1
	11~20	49	30.8
	21~30	36	22.6
	31~40	20	12.6
	41~50	5	3.1
	51~60	9	5.7
	over 60	8	5.0
	no response	4	

Table 3. BRT using data

		number	%
using frequency	none	68	41.7
	below 1day	46	28.2
	1day	11	6.7
	2days	16	9.8
	3days	10	6.1
	4days	4	2.5
	5days	3	1.8
	6days	2	1.2
	7days	3	1.8
purpose of using BRT	commute	17	17.9

	school	3	3.2
	business	14	14.7
	shopping	18	18.9
	eating out	2	2.1
	recreation	16	16.8
	hospital	6	6.3
	other	19	20.0
travel mode before moving into MAC	private car	41	43.6
	metro	26	27.7
	commute bus	3	3.2
	general bus	18	19.1
	taxi	3	3.2
	walking	2	2.1
	bicycle	1	1.1
	no response	1	
travel mode for departure BRT station	walking	68	73.1
	bicycle	5	5.4
	bus	12	12.9
	taxi	1	1.1
	private car	4	4.3
	other	3	3.2
	no response	2	
travel time for departure BRT station	~5min	40	46.5
	6~10	23	26.7
	11~15	12	14.0
	16~20	7	8.1
	over 20	4	4.7
	no response	9	
departure BRT station	Banseok	5	5.3
	South Terminal	1	1.1
	First town	87	91.6
	Government Complex	1	1.1
	Osong	1	1.1
waiting time in station	~5min	32	34.8
	6~10	39	42.4
	11~15	7	7.6
	16~20	14	15.2
	no response	3	
travel time on board	~5min	10	10.6
	6~10	25	26.6

	11~15	24	25.5
	16~20	28	29.8
	over 20	7	7.4
	no response	1	
arrival BRT station	Banseok	70	74.5
	South Terminal	1	1.1
	First town	4	4.3
	Seongnam high school	1	1.1
	Government Complex	14	14.9
	Doram	1	1.1
	Osong	3	3.2
	no response	1	
travel mode from arrival BRT station	walking	51	54.8
	bicycle	0	0.0
	bus	12	12.9
	taxi	1	1.1
	private car	3	3.2
	other	26	28
	no response	2	
travel time from arrival BRT station	~5min	35	40.7
	6~10	18	20.9
	11~15	7	8.1
	16~20	11	12.8
	over 20	15	17.4
	no response	9	
reason for using BRT	convenient access to BRT station	35.32	37.2
	inconvenient parking near the destination	10.16	10.7
	less congested	27.52	29.0
	less expensive	1.66	1.7
	for health and environment	1	1.1
	other	19.33	20.3

Table 4. Satisfaction level data for each element

	Level of satisfaction	number	%
overall impression	very satisfied	9	9.5
	satisfied	53	55.8
	neutral	26	27.4
	dissatisfied	6	6.3

	much dissatisfied	1	1.1
travel speed	very satisfied	18	18.9
	satisfied	48	50.5
	neutral	22	23.2
	dissatisfied	7	7.4
	much dissatisfied	0	0.0
frequency	very satisfied	13	13.7
	satisfied	36	37.9
	neutral	30	31.6
	dissatisfied	11	11.6
	much dissatisfied	5	5.3
reliability	very satisfied	24	25.3
	satisfied	45	47.4
	neutral	20	21.1
	dissatisfied	6	6.3
	much dissatisfied	0	0.0
service hours	very satisfied	16	16.8
	satisfied	41	43.2
	neutral	27	28.4
	dissatisfied	8	8.4
	much dissatisfied	3	3.2
image	very satisfied	7	7.4
	satisfied	30	31.6
	neutral	39	41.1
	dissatisfied	14	14.7
	much dissatisfied	5	5.3
vehicle	very satisfied	7	7.4
	satisfied	30	31.6
	neutral	44	46.3
	dissatisfied	13	13.7
	much dissatisfied	1	1.1
station	very satisfied	9	9.5
	satisfied	38	40.0
	neutral	40	42.1
	dissatisfied	8	8.4
	much dissatisfied	0	0.0
boarding time including fare collection system	very satisfied	13	13.7
	satisfied	43	45.3
	neutral	35	36.8
	dissatisfied	4	4.2
	much dissatisfied	0	0.0

fare level	very satisfied	5	5.3
	satisfied	26	27.4
	neutral	49	51.6
	dissatisfied	15	15.8
	much dissatisfied	0	0.0
transfer	very satisfied	10	10.5
	satisfied	39	41.1
	neutral	38	40.0
	dissatisfied	8	8.4
	much dissatisfied	0	0.0
information	very satisfied	5	5.3
	satisfied	31	32.6
	neutral	49	51.6
	dissatisfied	10	10.5
	much dissatisfied	0	0.0
access to station	very satisfied	13	13.7
	satisfied	34	35.8
	neutral	31	32.6
	dissatisfied	12	12.6
	much dissatisfied	5	5.3

Table 4-1. Average Satisfaction level in each element

	average satisfaction level	order
overall impression	**3.66**	
travel speed	3.81	2
frequency	3.43	7
reliability	3.92	1
service hours	3.62	4
image	3.21	12
vehicle	3.31	10
station	3.51	6
boarding time	3.68	3
fare level	3.22	11
transfer	3.54	5
information	3.33	9
access to station	3.40	8

1: much dissatisfactory ~ 5: very satisfactory

Table 4-2. Weighted percentage with multiple choice for most satisfactory element

	1st	%	2nd	%	weighted %
travel speed	30	33.0%	24	27.0%	31.0%
frequency	19	20.9%	8	9.0%	16.9%
reliability	19	20.9%	15	16.9%	19.5%
service hours	3	3.3%	7	7.9%	4.8%
image	1	1.1%	2	2.2%	1.5%
vehicle	4	4.4%	3	3.4%	4.1%
station	3	3.3%	9	10.1%	5.6%
boarding time	2	2.2%	3	3.4%	2.6%
fare level	0	0.0%	0	0.0%	0.0%
transfer	7	7.7%	9	10.1%	8.5%
information	0	0.0%	3	3.4%	1.1%
accessibility	3	3.3%	6	6.7%	4.4%
sum	91	100.0%	89	100.0%	100.0%

Table 4-3. Weighted percentage with multiple choice for most dissatisfactory element

	1st	%	2nd	%	weighted %
travel speed	3	3.4%	1	1.2%	2.7%
frequency	11	12.5%	7	8.2%	11.1%
reliability	0	0.0%	2	2.4%	0.8%
service hours	3	3.4%	5	5.9%	4.2%
image	17	19.3%	15	17.6%	18.8%
vehicle	7	8.0%	8	9.4%	8.4%
station	6	6.8%	7	8.2%	7.3%
boarding time	2	2.3%	2	2.4%	2.3%
fare level	14	15.9%	9	10.6%	14.1%
transfer	9	10.2%	8	9.4%	10.0%
information	7	8.0%	8	9.4%	8.4%
accessibility	9	10.2%	13	15.3%	11.9%
sum	88	1	85	1	

Table 5. Stated preference survey for improvements to increase BRT using

	importance level	order
faster	3.61	8
more frequent	3.99	4
increased service hours	3.93	5
improved image	3.42	10

higher capacity bus	3.49	9
weather protected station	3.80	6
off-board fare collection	3.46	11
less expensive	3.78	7
increased connectivity	4.07	2
improved information	4.02	3
improved accessibility	4.16	1

Table 5-1. Weighted percentage with multiple choice for the most important improvement

	1st	%	2nd	%	weighted %
faster	25	16.6%	11	7.4%	13.5%
more frequent	20	13.2%	25	16.8%	14.4%
increased service hours	16	10.6%	12	8.1%	9.7%
improved image	10	6.6%	6	4.0%	5.8%
higher capacity bus	6	4.0%	6	4.0%	4.0%
weather protected station	9	6.0%	11	7.4%	6.4%
off-board fare collection	8	5.3%	9	6.0%	5.5%
less expensive	26	17.2%	19	12.8%	15.7%
increased connectivity	7	4.6%	21	14.1%	7.8%
improved information	4	2.6%	7	4.7%	3.3%
improved accessibility	20	13.2%	22	14.8%	13.8%
sum	151		149		

Table 5-2. Response for the improvements

	number	%
change in a month	41	25.8
gradually change	112	70.4
not change	6	3.8