SOUTH KOREA'S EXPERIENCE WITH SMART INFRASTRUCTURE SERVICES

BUS MANAGEMENT SYSTEM

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CONTENTS

1. EXECUTIVE SUMMARY

The urban transportation problem caused by urbanization is becoming more serious, and, in particular, the rapidly increasing number of passenger cars in all cities is causing many problems such as traffic congestion, lack of roads and parking spaces, increased traffic accidents, and worsened air pollution. Supplying public mass transportation such as subways and Bus Rapid Transits (BRTs) with separated lanes can be a solution, but each city faces limitations in available land and financial resources. South Korea has successfully implemented various policies that maximize the efficiency and convenience of existing transportation facilities by applying excellent Information and Communication Technology (ICT). Notably, the Bus Management System (BMS) on public transit with ICT is the most representative. The BMS, which supports the increase in the efficiency of bus operation, guarantees the punctuality and service quality for both onboard passengers and waiting passengers at the bus stop. The implementation of bus-oriented public transportation policies based on the BMS implementation can mitigate the amount of traffic entering congested areas such as the central business district owing to a modal shift from private cars to public buses. The purpose of this research is to share the successful cases of the BMS, one of the leading services among the Intelligent Transport Systems (ITS) in South Korea.

First, this research explains the overall traffic environment and the derived problems on the public bus system in the past Korea and the necessity of introducing ITS, especially the BMS, which aims to reduce public transportation problems. Then, the definition of the BMS is explained in terms of its main technical contents, including data collection and processing, bus information provision, automatic fare collection, and applications of cutting-edge technologies. This research also describes the best practices of the BMS deployment within Seoul and Daejeon from the perspective of construction, operation, supportive policies, and effects.

Seoul, the capital of South Korea, and Daejeon, one of the metropolitan cities in South Korea, are similar in size with different urban environments. Seoul, the core city of the capital area and one of the biggest mega-cities in the world, has a population of approximately 10 million surrounded by many large satellite cities and is connected by well-developed urban railways and metro-bus lines for the commuting traffic. Daejeon has about five times the population and vehicles less than Seoul, but its traffic congestion is as severe. Two successful Korean cases can inspire the mega and metropolitan cities of Latin America Countries (LAC) and the Caribbean region that are trying to introduce and implement the BMS.

The BMS can further improve public transportation services and can have significant effects with a relatively small budget compared to metro and road construction. Seoul has already proven many positive effects through the establishment of BMS, and it provides a clue to the benchmarking of the LAC and the Caribbean region. However, considering the economic conditions of the LAC and Caribbean region, the implementation cost for Seoul presented in this paper can be taken into account for appropriate adoption of the BMS system. Based on Korea’s previous experiences, if LAC and the Caribbean region can find viable and sustainable methods based on these clues, they can also expect more positive effects than anticipated.

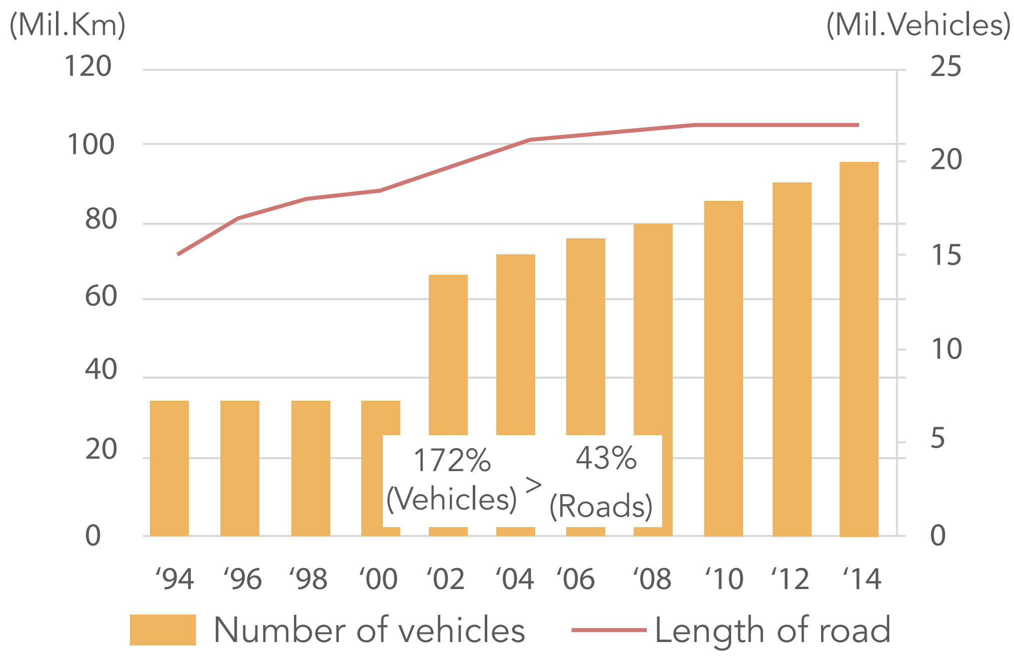
Consequently, this paper describes the implications and recommendations required to successfully introduce the BMS for LAC and the Caribbean region.

2. INTRODUCTION

Despite the complete destruction of infrastructure after the Korean War in the 1950s, Korea has achieved faster economic growth than any other country. However, rapid urbanization along with economic growth also caused many new problems, one of which was in the urban transportation. Roads and subways were built to solve the explosively increasing traffic demand, but it was still inadequate, leading to further problems such as the enormous cost and lack of land.

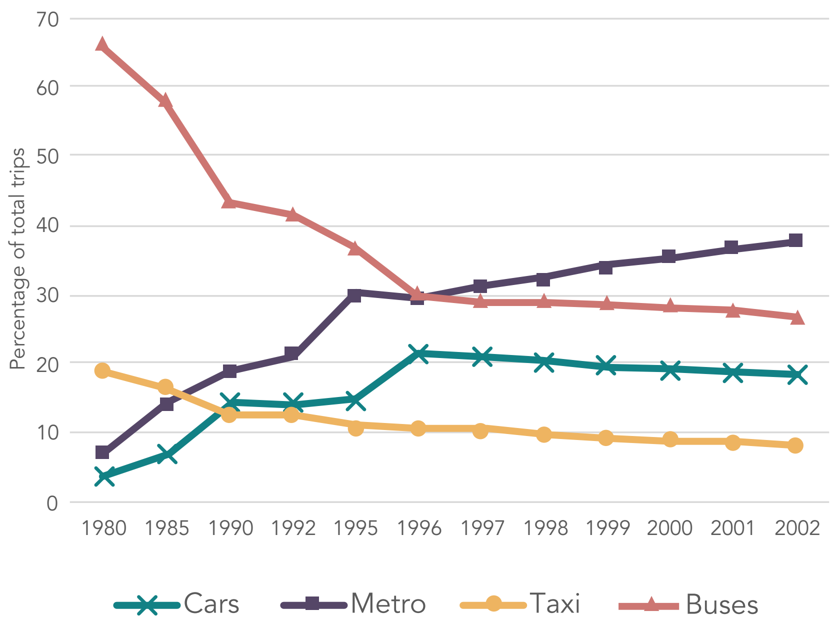
The capital city of Seoul is a mega-city with a population of 10 million, and the traffic congestion caused by passenger cars was so severe that the role of public transportation such as urban railways and buses began to play a more important role. The urban railway network has also expanded from 107.3km in 1980 to 264.7km in 1990, 469.6km in 2000, and 621.9km in 2015. However, the increase rate of roads construction was only 1/4 of that of passenger cars. Under these circumstances, the competitiveness of subways with high arrival accuracy was strengthened, while the bus services had become as poorer as a public transportation.

FIGURE 1. 1994~2014 INCREASE RATE (ROADS & VEHICLES) IN KOREA



As shown in Figure 2, the modal share of subways is steadily increased, but the modal share of buses is steadily decreased. At this time, in most major cities in South Korea, the downtown congestion had become a concern as the role of buses as public transportation was weakening.

FIGURE 2. 1980~2002 CHANGES OF PUBLIC TRANSPORTATION RIDERSHIP IN SEOUL



Accordingly, policies were introduced to maximize the efficiency of existing transportation facilities and public transportation in Seoul. In the 2000s, Seoul began to actively utilize ICT technology. The BMS can provide a better public transportation service by improving various problems of bus-oriented public transportation, and the effect can be further maximized with the Bus Rapid Transits (BRTs), bus lanes, and a public transportation electronic payment system.

In particular, in the major cities of Korea, various policies and technologies such as the BRT, BMS and BIS(Bus Information System), public transport integrated fare system, and electronic payment system mentioned above were applied together for public transportation reform. As a result, buses began to play a more significant role as a mode of public transportation over time, passenger convenience has improved, and the number of bus users has increased greatly. In the next chapter, the organization and operation of the Korean BMS will be explained.

3. KOREA'S EXPERIENCES

This chapter will examine at the Korean BMS, a key technology that has made it possible to successfully operate buses as public transportation.

3.1 BACKGROUND OF BMS

From the late 1990s to the early 2000s, bus services as public transportation had many issues. The biggest problem was that the buses were not running on schedule. The unpunctuality issue was partly due to the increased bus travel time caused by traffic delay in urban areas. The buses also did not follow the dispatch interval at the first departure from the garage and the drivers of the same bus route were unaware of the current locations of each other. In other words, keeping on-schedule operation was difficult to maintain as there was no real-time monitoring system that would inform the bus drivers of their locations to each other, the traffic condition, initial departure time, and

dispatch intervals. The competitiveness of the buses was relatively weak in terms of punctual operation on schedule, compared with subways that can arrive and depart at each station as scheduled. The bus drivers also tried to shorten the driving time to secure the bus company's profit and break time for themselves. As a result, it caused frequent abnormal operations such as abusive driving, speeding, deviation from the route and no-stop passing at stations. The problem here is that Seoul had no means to monitor this particular public transportation in spite of these abnormal operations happened.

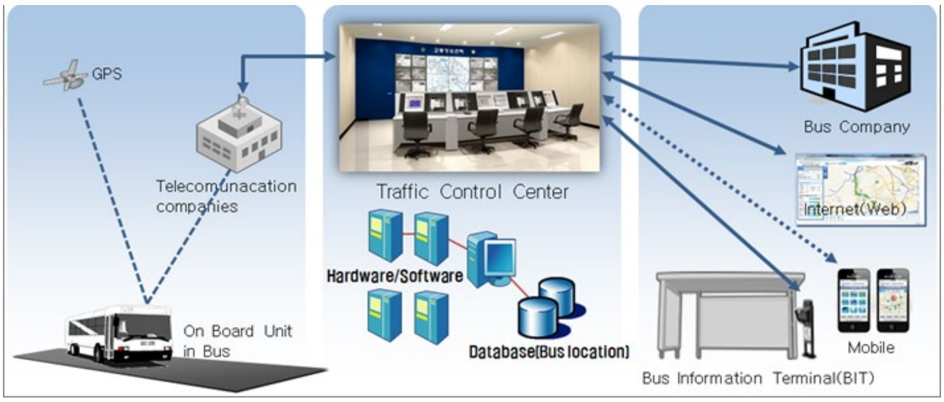
Also, from the user's point of view, the lack of information on bus arrival/departure time at the station lessened the attraction of the users as they increasingly preferred the subway which provides such information with relatively high accuracy. The lack of punctuality, over speed/abusive driving, non-stop passing, and lack of arrival/departure information on the real-time in bus operation caused complaints of bus users to continue, which led to a decrease in modal share of buses. As an alternative to addressing many problems of buses for public transportation, the importance of the BMS has been emphasized, and its implementation began in Seoul since the early 2000s.

3.2 DEFINITION OF BMS

The Bus Management System (BMS) and the Bus Information System (BIS) are currently used almost without distinction within the territory of Korea as the BMS and the BIS perform the same process that collects bus's real-time location in real time and provides the collected data to users after converting it to meaningful information. In some cases, the Bus Information & Management System (BIMS) is used as a common term for both the BMS and the BIS.

Nevertheless, explaining the differences between the BMS and the BIS, each system can be distinguished by whom it is operated for. In other words, the BMS focuses on bus operation and management and functions as the system for bus operators and bus policy makers. The BIS, on the other hand, is the system for bus users as it focuses on providing bus arrival information to improve convenience of bus use.

FIGURE 3. CONCEPT OF BMS AND BIS



More specifically, the BMS is the system aiming to raise the bus's competitiveness as a public transportation by planning reasonable bus policy. So, BMS is used to improve punctuality in operation and driving behavior and to provide a variety of bus information, and to track historical operation data. The Traffic Control Center (TCC) is the center of all bus management strategies playing the key role in executing most strategies, the BIS improves the convenience of bus users by providing information that is generated at the TCC where real-time bus location is collected, analyzed and processed. To this

end, it focuses on information provision services by building systems as the Bus Information Terminal (BIT), Internet website, Automatic Response Service (ARS), and mobile service. In Korea, each local government manages the projects and public transportation policies. The private bus companies own their buses but operate and manage them under the BMS and the BIS which are designed and controlled by the local governments.

TABLE 1. COMPARISON BIS WITH BMS

CATEGORY	BIS (BUS INFORMATION SYSTEM)	BMS (BUS MANAGEMENT SYSTEM)
Organization in Charge	·Local government	·Local government
Purpose	·Providing information service	·Monitoring and controlling bus operation
Methods & Devices	·BIT and displays at bus station ·Internet, mobile service	·Console of bus company, situation monitoring room, in-vehicle devices
Target object	·Bus users	·Bus drivers, bus companies, local governments
Provided Information	·Previous station departure/arrival info (Event data)	·Operation status data (data transmitted regular interval
In common	· GPS, wireless communication, OBU (on-board unit) · Center system (computer equipment, network, additional facilities, etc.) · Operating system (operating & application software)	

3.3 BMS DATA COLLECTION SYSTEM

The most basic system for the BMS is data collection system that identifies the exact current location of the bus and sending it to the center quickly. It is directly related to the accuracy of information processed at the center in the future, therefore Data Collection System is very important for producing reliable information. The data collection system can be classified into two types: a location tracking technology, which identifies the current location, and a wireless communication technology, which transmits the identified location to the center.

As for the location tracking technology, the link-based Global Positioning System (GPS) are currently used in South Korea. In the beginning of the BMS, technologies, other than the GPS, were also used including, the Radio Frequency (RF) base station (beacon method) and the Dedicated Short-Range Communications (DSRC), both of which are location detecting devices installed on roadsides. There are several reasons why GPS is now widely used for BMS in Korea.

First, it is much more economical than other options. To use the roadside-installed positioning technology, the base stations must be established all along the route, and additional base stations should be built in case of opening a new route. In addition, maintenance on base station equipment is required on a regular basis for

a stable operation. On the other hand, GPS has little initial investment cost since there are no devices to install on the road. There is no additional cost for opening new routes and maintenance costs are not incurred, either.

Second, the accuracy of the GPS location technology is excellent. In the beginning of the BMS, it was difficult to pinpoint the exact location due to the interference of the tall building in the Central Business District (CBD). With increased satellites and the combination of the tracking locations with mobile communications, the accuracy issues have been improved greatly. Today, the real-time detection of bus locations is available with a very high accuracy even within the CBD.

Third, the GPS technology is not influenced by the weather and is unlikely to provide erroneous data, and therefore, collection of reliable data is guaranteed. The roadside-installed location-tracking technology, on the other hand, often produces information according to the changes in weather conditions such as fogs, rain, snow, and more. However, the GPS is rarely influenced by such weather changes, and stable and reliable location data can be obtained. In addition to the economic efficiency, reliability, and stability of GPS stated above, its data transmission speed is very fast without limitations in identifying the position whenever necessary. However, the GPS also has its downside: it cannot detect or receive data when the vehicles are under the overpass or inside a tunnel. Therefore, this suggests that the use of roadside-installed location-tracking technology may be the alternative in such areas when implementing the BMS.

While the GPS can collect such data with efficacy, a wireless communication technology is required to transmit the collected bus location data to the center. In South Korea, the most widely used wireless communication technology is the Code-Division Multiple Access (CDMA), and more than 70% of the cities are using CDMA to transmit the real-time position data to the center. In addition, wireless data, DSRC, and Trunked Radio System (TRS) are also utilized, and two or more of such communication methods can be used together. There are several reasons why CDMA is currently widely used in South Korea.
First, it allows reliable data transmission. Since CDMA is widely used as a commercial network with as wider data transmitting area compared with other, communication between the bus and the center can be reliably made regardless of its location.

Second, the CDMA is also very economically efficient. It does not require an additional implementation for infrastructure at the initial stage and can be expanded without separate investment costs; hence, it has the advantage of rarely incurring construction costs. However, in terms of operating costs, there are incurring communication costs per unit, and thus, local governments and operators used to have a relatively big burden to make use of the CDMA. However, the cost of communication used for the public use has been lowered recently.

Third, it has a high scalability. Currently, the BMS is actively deployed for the buses operating from city to city as well as the buses operating in a city, and the connection is quite smooth for inter-city BMS implementation.

In spite of these advantages, the CDMA is usually leased from the private operator for reliable telecommunication network, which contributes to the limitations that the center operator tends to rely on private telecommunication companies in case of communication failure and error. As mentioned earlier, the CDMA is the most widely used technology for the transmission of the real-time position to the center in South Korea. However, in the early stage of the BMS, wireless data, DSRC, and TRS were used in various cities, and some are still in use. In addition, there is a trend in introducing the Long-Term Evolution (LTE) system on the BMS, which is currently used for a mobile communication network. This suggests that you should consider the economic efficiency, stability, and scalability based on the characteristics of each area when choosing the optimal communication method as the wireless communication technology is developing rapidly.

TABLE 2. NUMBER OF CITIES BY WIRELESS COMMUNICATION TECHNOLOGY IN SOUTH KOREA

CATEGORY	CDMA	WIRELESS DATA	DSRC	TRS	OTHERS(MIXED)	TOTAL
No. of cities	53	5	4	4	9	75

As explained above, the real-time bus data is collected using both the location tracking technology and the wireless communication technology. Depending on the data collection strategy, it can be divided into a periodic collection by regular cycle and an event-oriented collection.
The periodic collection method collects data at fixed time intervals and transmits the collected location data to the centers by fixed time intervals. In South Korea, the time interval for the periodic collecting is set to 30 seconds. However, when traffic flow is very fast or when the intervals between the bus stations or between the intersections are short, collecting data every 30 seconds may miss some of the important data.

The event-oriented collecting method collects the data whenever the defined event, such as vehicles passing through an intersection, or arriving and departing at the bus station, and incidents, is detected. In cases where traffic congestions occur or where intervals between the bus stations or intersections are long, the real time bus location data cannot be collected over long periods of time. As stated above, both methods have disadvantages, and both methods are used to collect more accurate data in South Korea. In other words, the bus location data is basically collected at a regular period (mainly 30 seconds), and the data is also collected at the event points such as at the intersections and bus stations.

3.4 DATA PROCESS FOR BMS

The collected bus location data is transmitted to the center and processed through the information processing system into meaningful information such as the interval between the previous and the next buses, the travel speed, the travel time, and the estimated arrival time at the station. The interval data among previous, current and next buses is the basic data for monitoring the current bus operation status by each route since it calculates the time and distance of the previous and next buses that are currently driving on the same route. The purpose of this is to efficiently control the interval among buses and to the buses to arrive at each bus stop according to the planned timetable, thereby contributing to punctual operation. Through in-vehicle device, bus drivers can get information about where the previous and next buses are running on the same route and what the interval time among them are. Based on this data, the drivers can decide whether to speed up or down on their route.

Travel speed and travel time refer to the travel speed and time between nodes which are the important points on the road, such as bus stations, intersections, landmarks, and etc. Travel time is calculated based on the time that the buses pass intersections and stops, and the travel speed is calculated by dividing the calculated travel time by the distance of link which connects one node to the next node. Such travel time and traffic speed are used as important data to figure out the overall traffic pattern of the city, and it can be also used for the ground data to establish traffic related policies by analyzing the causes of traffic congestion areas.

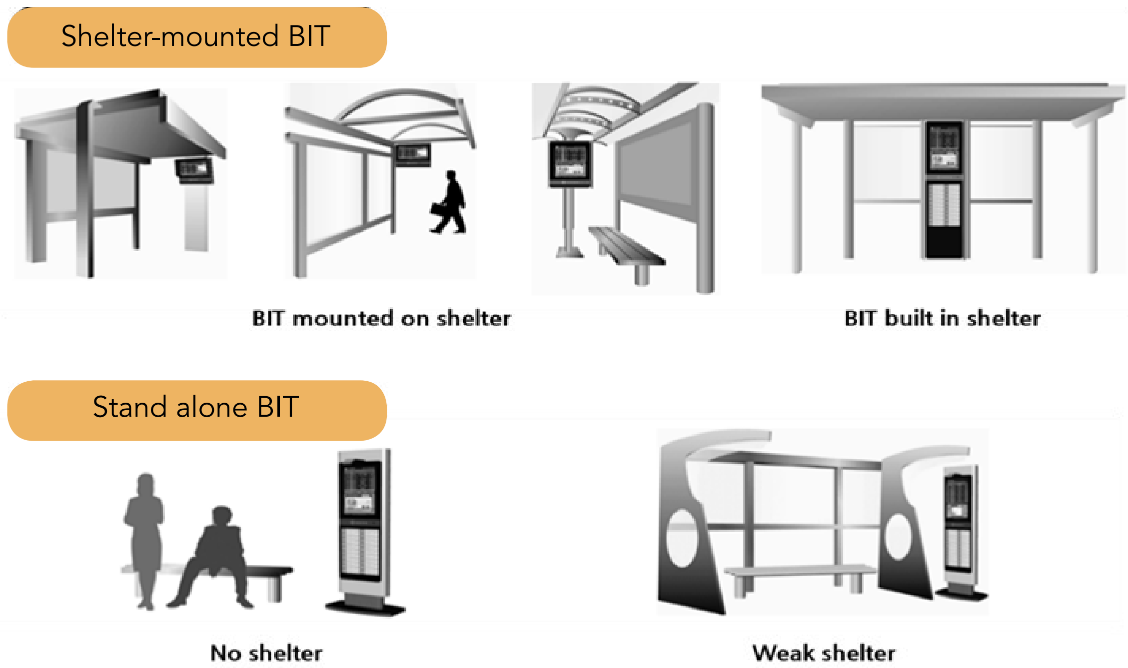
The estimated arrival time of buses is to inform people when the next bus for each route arrives at every bus station. It is the most necessary information for users who are waiting for buses at the bus stop, and the estimated time of arrival is provided via apps. on mobile phones, minimizing unnecessary waiting time at the bus stop. The estimated time of arrival of buses is calculated through

the algorithms for travel time prediction by the moving averaging method, simple averaging method, previous bus travel time utilization method, Kalman filtering, and neural network model. In South Korea, both moving average method and simple moving average method are popularly used, with a using rate of about 67%. In addition, there have many recent cases in which optimal arrival information is calculated by using two or more algorithms according to the quantity or quality of collected data.

3.5 INFORMATION PROVISION THROUGH BUS INFORMATION TERMINAL (BIT)

Information generated from the data processing is provided to bus users, bus drivers, bus companies, and local government officers (operators at the centers) in charge of bus management through information provision systems. First, bus users are provided with various information on bus arrival, transfer, route, first and last bus time via the Bus Information Terminal (BIT), smart phone, and the on-line platform. By providing this information, it will improve the bus user's convenience by reducing the waiting time at the stations and enabling them to use the remained time doing other tasks before bus's arrival. The installed BIT at bus stations are classified as shelter-mounted and stand-alone, depending on the installation type, and classified into Light Emitting Diode (LED) and Liquid Crystal Display (LCD), depending on the display type.

FIGURE 4. BIT TYPES BY INSTALLATION METHOD



While the provided information may be presented slightly different depending on if the display type is LED or LCD, the core information related to the buses' current operating conditions is provided by default such as route guidance, expected bus arrival time and current location status.
The bus drivers receive various information such as the interval time and current position of the previous and next buses, bus operation status, traffic condition on the route, notification of violated driving, and city news through the installed device in the bus.

FIGURE 5. IN-VEHICLE DEVICE FOR BUS DRIVERS

Bus companies receive the information on bus operations such as real-time bus operation status, incidents, and traffic conditions from the center, and utilize them for systematic and efficient dispatch and bus management. The provided information on the BMS for each stakeholder and by device is summarized in Table 3 and 4.

TABLE 3. PROVIDED INFORMATION BY STAKEHOLDER

STAKEHOLDER	PROVIDED INFO	DETAILS
Bus User	Bus Routes	·Bus route, shortest route, bus stop information, transfer
	Bus arrival time, delay	·Bus location, estimated time of arrival, previous departure status, waiting time, reason for delay
	Bus station location	·Bus station location, routes operating at the bus station
	Nearby Transfer	·Linked information with subway, connected transportation mode (rail, metro, other bus line, etc.)
	Other	·Bus timetable, first & last bus time, dispatch interval, etc.
Bus Driver	Interval distance	·Interval distance and time among previous, current, next buses
	Bus operation status	·Bus location, speed, remaining distance, end station arrival time, etc.
	Traffic condition on route	·Accident, congestion, delay time on the route
	Monitored situation	·Speeding, non-stop passing, deviation from routes
Bus Company	Bus operation status	·Location, operation area, average speed, travel time, check of speeding
	Real time monitoring	·Bus operation status monitoring information, operation history statistics information
	Incidents	·Accident, breakdown, deviation from routes, bus operation with door opened, bus return point (or garage)

TABLE 4. PROVIDED INFORMATION BY DEVICES ON BM

DEVICE	PROVIDED INFORMATION	
In vehicle (Bus) device	·Intervals between previous/next bus ·Traffic condition ·Deviation from routes	·Incident information ·Bus operation with door opened ·Center
BIT	·Real time bus operation status on route ·Dispatch interval, first & last bus time ·Route Information	·Nearby public transfer information ·Traffic condition and Incidents Information
On-line platform	·Bus operation information (road, bus company, route, bus stations, first & last bus time, transfer, fare, dispatch interval) ·Optimal route information (travel distance, time, cost, number of transfers)	·Incident information ·Statistical analysis of operational information (operator only) ·Nearby public transfer information
Mobile Phone (Smart Phone)	·Bus operation information ·Optimal route information ·Route information by transportation mode	·Bus station information
Traffic Monitoring Room & devices	·Bus operation information ·Incident Information	·Route/bus station Information ·Operation History

4. CASE STUDY

In this chapter, we will examine the key element of successful public transportation reform and the BMS implementation in Seoul and Daejeon in South Korea.

4.1 SEOUL

Seoul, the capital of South Korea, is located in the center of the Korean peninsula and is a megacity with an area of about 605 square kilometers and a population of 10 million. Seoul, with only 0.6% of the total area of South Korea, is densely populated with about 20% of the total population. Considering the metropolitan area surrounding Seoul, it shows that nearly half of the population is now living in which is about 11.8% of the country's total area. This is a clear indication of the severe population concentration in the capital area, which is the biggest cause of serious traffic congestion in Seoul and the metropolitan area.

The following table shows key indicators related to transportation in Seoul, showing 3,124,000 passenger cars registered as of 2018, traffic speed about 24 km/h, total length of road 8,246 km, total length of subway 342.6 km and the BRT 128 km as of 2018.

TABLE 5. TRAFFIC-RELATED KEY INDICATORS IN SEOUL

CATEGORY		UNIT	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
POPULATION AND TRAFFIC STATUS	POPULATION OF SEOUL	THOUSAND	10,421	10,456	10,464	10,575	10,529	10,442	10,388	10,369	10,297	10,204	10,124	10,049
	(METROPOLITAN AREA)		(24,472)	(24,726)	(24,950)	(25,456)	(25,620)	(25,715)	(25,867)	(26,037)	(26,173)	(26,297)	(26,391)	(26,513)
	NO. OF VEHICLES	THOUSAND	2,933	2,949	2,954	2,981	2,978	2,969	2,973	3,013	3,057	3,083	3,116	3,124
	(PASSENGER CAR)		(2,205)	(2,225)	(2,248)	(2,283)	(2,302)	(2,317)	(2,338)	(2,387)	(2,437)	(2,475)	(2,513)	(2,526)
	SPEED	km/H	23.4	24.4	24.0	24.0	......	......	26.4	25.7	25.2	24.2	24.2	......
	(CBD)		(14.4)	(16.7)	(16.0)	(16.6)			(18.7)	(17.4)	(17.9)	(20.2)	(19.0)	
TRAFFIC FACILITIES	LENGTH OF ROAD	km	8,078	8,093	8,102	8,142	8,148	8,174	8,197	8,214	8,215	8,241	8,243	8,246
	RATE OF ROAD	%	21.83	21.89	21.96	22.02	22.06	22.24	22.32	22.42	22.43	22.66	22.71	22.72
	LENGTH OF SUBWAY	km	286.9	286.9	313.9	316.9	316.9	327.1	327.1	327.1	331.6	331.6	342.6	342.6
	LENGTH OF BRT	km	67.9	75.9	92.6	100.4	114.3	115.3	115.3	117.5	119.3	119.3	121.1	128.8
	LENGTH OF BICYCLE LANE	km	715.5	728.8	764.4	829.5	804.2	674.0	707.6	724.7	778.8	868.7	888.7	916.0

While the population of Seoul is decreasing slightly, the number of cars, and length of road and subway are steadily increasing. In particular, the table also shows an increasing implementation of the BRT and bicycle lanes.

The bus services in Seoul as public transportation had completely lost its competitiveness compared to that of the subway in the 2000s, and the number of bus companies in Seoul dropped from 103 in 1997 to 57 in 2003, and the bus service was gradually becoming a declining industry. The availability of more accurate and reliable public transportation, namely the subway, along with other rooted problems in the industry, provided the public transportation users a reason to prefer the subway over the bus.

Bus companies were fiercely competing for the so-called "golden routes" that were guaranteed profitability, which caused unprofitable routes to suddenly stop operations, resulting in the inconveniences for the users. In addition, bus drivers frequently committed the illegal operation while the bus companies promoted excessive competition such as dispatching irregular intervals, abusive driving, refusal of passengers, non-stop passing at the stations to secure more passengers; the quality of bus services worsened day by day.

The poor bus services led to the increase in car users, resulting in severe road congestion, which was the biggest cause of the unpunctual bus operation. This situation in turn led to a decrease in users and deterioration in the management of the bus companies, causing a vicious cycle. In order to solve the chronic problems, Seoul Metropolitan Government began the public transportation reform in 2004 and conducted related research to seek for solutions continuously.

The first was to build a unified transportation system by combining the individualized components of public transportation in Seoul. In other words, it was an attempt to integrate public transport components, which used to operate independently, by area such as bus route, fare system, and

traffic card. To efficiently deal with this, it also included building a traffic information system and the BRT, introduction of advanced buses, and implementation of the BMS. To this end, a reorganization of bus routes was proposed in order to link the trunk line and feeder line to the subway line organically. Also, by introducing the distance-based fare system, passengers traveling the same distance with several transfers can pay the same fare. The integrated transportation card system allowed people to use all public transportation in Seoul with a single card. In addition, ITS services such as the BMS and automatic enforcement system were implemented to improve the convenience of public transportation. After the public transportation reform, the declining number of bus passengers began to increase, with more than 99% of citizens using transportation cards in order to pay the public transportation fare. More than 75% of citizens are also found to be satisfied with using public transportation in Seoul, with the total share of public transportation increasing.

The second direction of public transport reform was the introduction of quasi-public bus systems. Until this time, buses in Seoul were operated by the private sector. As a result, there had been various problems such as duplication of routes on profitable routes, excessive competition among companies, and abusive driving to increase profitability. In order to build a unified transportation system, it was necessary to introduce a bus completion system. Through quasi-public bus systems, Seoul guaranteed the operating rights to bus companies while the city authority secured the right to determine the operation routes and bus schedules by guaranteeing the bus companies minimum profit and allocating revenue based on operational performance and evaluation. To promote citizen's convenience by improving service level for public interest, Seoul actively engaged in essential parts for the bus operation.

In addition, the median bus-only lanes, the construction of transfer centers, the upgrading of buses, and the creation of public parking lots were also examined at this time for the implementation of the BRT. The Seoul government also reviewed the comprehensive budget plan for these facilities since they require much more budget than just building the BMS. However, this initiative faced fierce opposition from the bus companies that were leading the bus route decision and operation at that time. Under quasi-public bus systems in Seoul, the bus lines would be converted into open public bidding system and Seoul could manage and monitor the bus operation status through the BMS. Therefore, it was natural for the bus companies to oppose it.

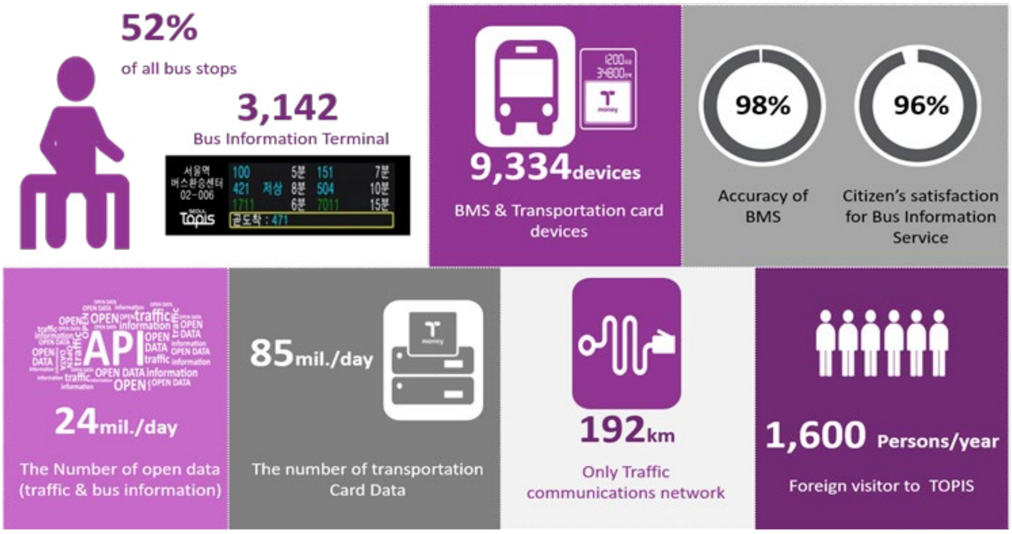
In order to break through these challenges, Seoul organized a "Bus Reform Citizens Committee" with civic groups, experts, bus companies and city councils. The committee deeply reviewed and discussed the related issues and seek solutions. Meanwhile, Seoul tried to consistently explained and persuaded bus companies and bus workers to finally reach an agreement between Seoul and the bus association.
The success factors of the public transportation reform in Seoul can be stated as three, the active leadership of the city with strong willingness, persistent consultation and discussions among all the related stakeholders, and the consensus among citizens that the bus reform is the only solution to address the serious traffic problems. This public transport reform of Seoul can be a reference case for many Latin American countries suffering from chronic traffic congestion due to the low share of public transportation.

First, the BMS provides a convenient, seamless, competitive public transportation service by integrated operation of bus-dedicated lanes and transportation cards. It contributes to maintain modal share of public transport above a certain level of share in Seoul transportation.

Second, the BMS enables the entire road traffic system to maintain a level of service. It helps passenger cars to flow smoothly with the implementation of various road management systems, automatic illegal parking enforcement systems, and incident detection systems under the condition of keeping the modal share of public transportation above a certain level.

As a result, regardless of transportation mode, citizens' satisfaction has been increased, and also a proper modal share among different transportation methods could be achieved. The BMS center monitors the operation of about 9,300 buses in Seoul in real time and provides bus information to users through the BMS operation. Seoul required that all buses should be installed with a terminal that can be detected in real time to collect the bus's real-time operation such as the current location, speed, rapid acceleration, sudden stop, non-stop passing at the station, deviation for the route, and open-door driving. The terminal also includes a function as a transportation card validator and can collect the status of bus boarding and alighting, whose data reaches 85 million collected per day.

FIGURE 6. CURRENT CONDITION OF SEOUL BMS



Taking an example of service development by public, Seoul originally developed the BMS with a focus on bus management. However, a citizen independently developed a bus passenger-oriented application providing bus arrival information under the Seoul's data sharing policy. This APP was so popular and widely used for its convenience. In terms of the cost for building BMSs since 2003 to the present, it took about $4 million for on-board units (OBUs) installed on more than 9,000 buses and about $22.5 million for BITs installed at more than 1,000 bus stations, totaling about $26.5 million. This amount accounts for about 18.1% of Seoul's total ITS implementation costs. In addition, the center includes information processing software including center hardware and algorithms that collect, process and provide location information from buses in real time; information provision; connection server; and operation software to provide bus information through on-line platform to bus stations.

TABLE 6. SEOUL'S BUDGET INVESTED ON BMS

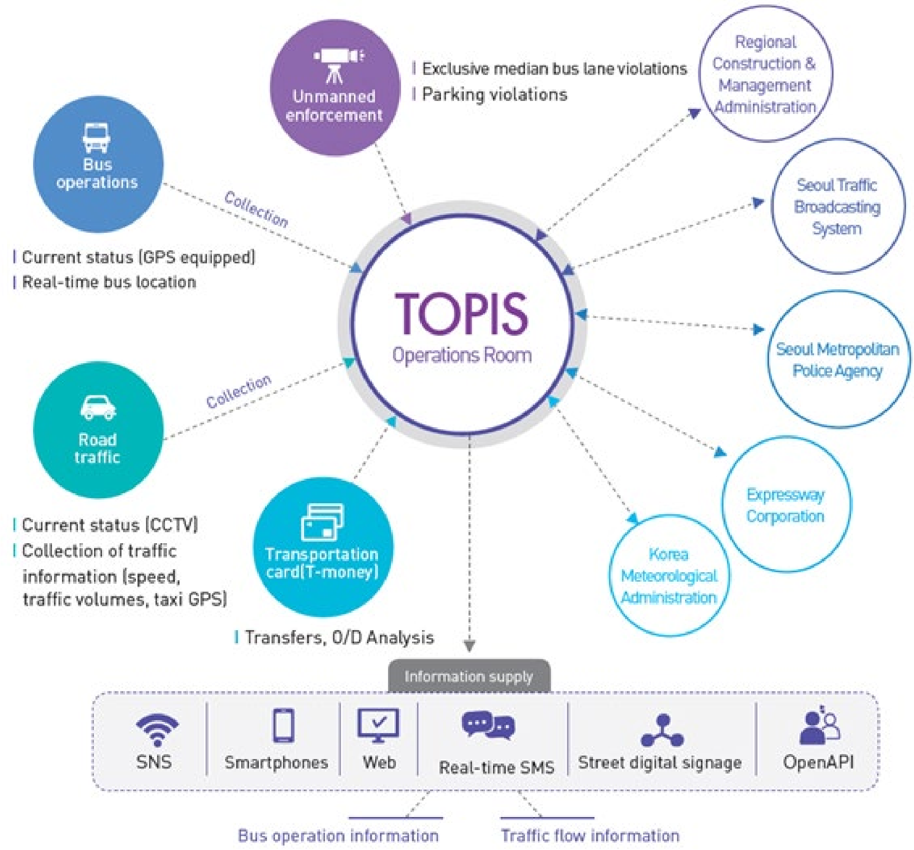
CATEGORY	INVESTMENT (THOUSAND US$)	
FIELD SITS FOR BMS	IN-VEHICLE DEVICES	BIT AT BUS STATIONS
	3,965	22,540

As illustrated above, the BMS requires a relatively small budget compared to that required for the construction of roads or metro. Nevertheless, it may be burdensome for bus companies to make investments to cover the costs of installing the on-board units required for the BMS. Therefore,

all budgets required for the BMS were invested by Seoul Metropolitan Government. In the case of automatic fare collection system introduced with the BMS, the initial investment cost could be reduced by taking the public private partnership (PPP). Private companies were able to retrieve some of their investment through collecting bus fare revenues. However, adopting the integrated fare system and fare discount to improve the public transportation service caused the bus companies' income to decrease. To solve this deficit, Seoul Metropolitan Government provided a direct financial subsidy to offset the reduced income by introducing a quasi-public transportation system. The annual subsidy paid by the Seoul Metropolitan Government to compensate private bus operators amounts to about $200 million to $300 million.

Among the various effects achieved through the BMS, the most important effect is the increase in the number of people using the public transportation. The increase in the number of public transport users in Seoul is a result achieved through a major policy change called public transport reform. The average number of passengers per day using public transport, including subways and buses in Seoul, has been steadily increasing since the public transport reform and TOPIS were established in 2004.
Before TOPIS, various data related to transportation such as public transportation, urban expressway, incidents, CCTV, road work and enforcement data were separately managed, and, therefore, data utilization was inefficient and could not provide user-oriented service to improve convenience. In addition, TOPIS provided a solid foundation to make transportation more convenient in Seoul by predicting future traffic conditions, introducing new services, and establishing scientific and reliable traffic-related policies.

FIGURE 7. MAIN FUNCTIONS OF TOPIS



According to the table 7, the share of public transport has been declining. However, through the public transport reform in 2004, it has steadily increased and is now currently reaching at as high as 65%. This is significantly higher than some of the major international metropolitan cities. In addition, the portion of sharing is well ahead compared with other cities such as Paris and Tokyo, where the public transportation network is well developed, and modal share exceeds 50%.

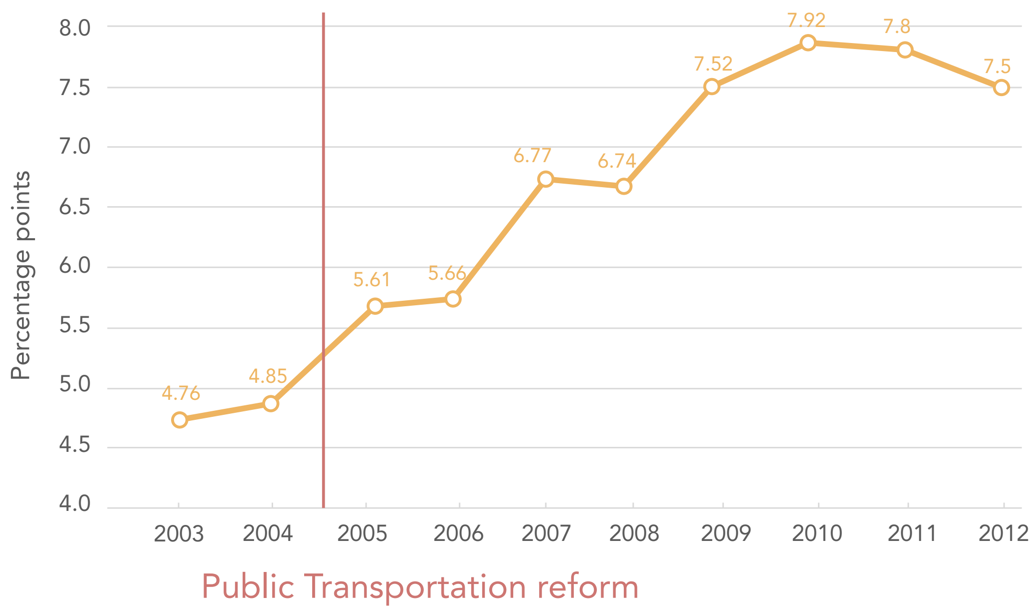
TABLE 7. CHANGES OF THE MODAL SHARE IN SEOUL

CATEGORY	2002	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PUBLIC TRANSPORTATION	60.6	62.3	62.5	62.8	63.0	64.3	65.1	65.6	65.9	66.0	65.8	65.0	65.0
BUS	(26.0)	(27.6)	(27.6)	(27.8)	(27.8)	(28.1)	(28.0)	(27.4)	(27.1)	(27.0)	(26.5)	(26.1)	(25.1)
METRO	(34.6)	(34.7)	(34.9)	(35.0)	(35.2)	(36.2)	(37.1)	(38.2)	(38.8)	(39.0)	(39.3)	(38.9)	(39.9)
PASSENGER CAR	26.9	26.3	26.3	26.0	25.9	24.1	23.5	23.1	22.9	22.8	23.0	24.3	24.4
TAXI	7.4	6.3	6.2	6.2	6.2	7.2	7.0	6.9	6.8	6.8	6.8	6.6	6.5
ETC.	5.1	5.1	5.0	5.0	4.9	4.4	4.4	4.4	4.4	4.4	4.4	4.1	4.1

The average vehicle speed increased from 22.9 km/h in 2000, before the public transportation reform, to 24 km/h in 2010, after the reform. The share of public transportation increased from 26% in 2002 to 28.1% in 2010. This high level of satisfaction led to active use of public transportation and to refrain from using passenger car, ultimately contributing to easing traffic congestion.

The citizens' satisfaction with public transportation in Seoul has been steadily increasing and is now reaching about 75%. Such high satisfaction leads to the activation of public transportation use and the decrease of the use of private cars, which ultimately contributes to lessened traffic congestion.

FIGURE 8. CHANGES SATISFACTION WITH PUBLIC TRANSPORTATION IN SEOUL



4.2 DAEJEON

Daejeon is located in the geographical center of the Korean Peninsula and covers an area of 539.34 km^2. It is a metropolitan city with a population of about 1.5 million, making it the fifth largest city in South Korea. Daejeon was the first city in South Korea to run a roadside bus lane in 1983 as a demonstration. In 2002, the BMS was introduced and operated in Daejeon. Like other major cities, Daejeon has experienced a steady increase in the number of automobile registrations from about 457,000 in 2002 to 674,000 in 2019.

The BMS project in Daejeon City was first designated as one of the ITS Model City, to present the promotion model of the city ITS project ahead of the 2002 World Cup. Daejeon ITS Model City built a BMS with a traffic management system and an electronic payment system, and out of a total of $19 million, a budget of $2 million was put into the BMS. The BMS project budget consisted of 74% of national expenses, 23% municipal expenses, and 3% private sector. After the introduction of the BMS, in the post-evaluation, citizens were most satisfied with the improvement of bus visibility, and the economic analysis of the BMS project showed that the benefit and cost ratio was 3.23.

In Daejeon where public buses have played a key role as public transportation, serious traffic has been heavily induced by passenger cars and buses. In order to solve the problem, the city government reformed the system of public transportation, in accordance with the deterioration of profitability of companies and the decrease in the number of people using public transportation in 2005; and introduced a quasi-public bus system and a free transfer system like Seoul. In addition, when the Metro Line 1 became operational in 2006, the bus routes were modified to eliminate overlapping routes and to be linked with the metro system, so that the users can transfer between both systems at no additional costs or at a discounted rate.

Afterwards, the BMS was reorganized with an additional budget of approximately $4 million along with the opening of the urban railway and the general bus route in 2009. In 2015, the bus connecting between Daejeon and Sejong City, a new administrative capital of South Korea nearby Daejeon, also provided bus information to citizens. In 2017, similar projects with the neighboring Gyeryong City were promoted. Currently, all buses that connect to neighboring local governments around Daejeon through the BMS are in operation. In Daejeon, 13 bus companies, 99 routes, and 1,016 buses are in operation, with an average of 420,000 passengers daily. The share of public transportation including metro and buses in Daejeon is about 26% as of 2018, which is lower than that of Seoul, 65%.

In the 2000s, Daejeon City paid oil subsidies and financial aid from 2001 due to a decrease in passengers, an increase in the number of automobiles and income, and an increased deficit in the bus company. In particular, the amount of financial aid paid in 2001 increased by more than 15 times from $3.2 million to about $48 million in 2019 due to the introduction of a free transfer system with metro and reduced transportation income.

Daejeon City has made the most innovative attempts with the introduction of the BMS to improve public transportation services. First, curbside bus-only lanes were introduced for the first time in South Korea, and this led to the introduction of bus-only lanes in each city. Currently in Daejeon, 44.5 km of the curbside bus-only lanes and 26.2 km of the median bus-only lanes are in operation. In addition, from 2016, the city has been operating a bus route on the 53km-long BRT which connects the city to Sejong City and Osong Station.

As the construction of a BMS for buses across the city was in progress, a prepaid transportation card was introduced from 2003 and a credit card-based postpaid transportation card was introduced in 2004. In the same year, an unregistered prepaid transportation card was also introduced, which was a release of nationwide compatible transportation card. Since 2007, the integrated fare system and transfer discount system have been implemented in connection with metro, express buses, and feeder buses.
In 2008, Daejeon City introduced a moving enforcement system is called the Eagle Eye Bus (EEB) for the

first time in Korea. The EEB's objective was to crack down on vehicles other than buses that illegally use bus-only lanes and vehicles that park on bus-only lanes.

The EEB is a system that installs a control camera on a bus to crack down on violations while moving and capturing the image of the violating vehicles. As a result, parking in the bus-only lanes has significantly been reduced, allowing buses to use the lanes without unnecessary traffic. In addition, the construction of the Tram, or Metro Line 2, is currently in construction on a 36.6 km-section that circulates the entire city on a 35-station scale of 35 stations, aiming to open in 2025.

When the BMS was introduced in 2003, the first DSRC OBU and RSE (Roadside Equipment) was installed to collect bus locations and traffic data, and the level of technology for collecting bus locations was transformed by GPS with cellular data in 2009. In addition, Korea has continuously made investments to expand the BMS system with neighboring cities such as Sejong and Gyeryong City.

5. IMPLICATIONS AND RECOMMENDATIONS FOR LAC COUNTRIES

Considering the successful experience of solving the traffic problems in the case study reviewing the BMS, there are few suggested alternatives for the cities of Latin America that are suffering from traffic problems, including congestion, as follows.

5.1 WELL-ORGANIZED PLANNING AND STRONG GOVERNANCE AS A DECISION-MAKER

The best solution to addressing the imbalance between traffic demand and supply is a policy to increase the modal share of public transportation. In order to improve the share of public transportation modes especially of bus services, the system of major public transportation in the LAC and the Caribbean region, needs to be drastically improved. In order to improve the bus service itself, the introduction of the BMS that can improve the on-time bus arrival with excellent route operations and transportation capability can be a viable solution.

First, in order to successfully introduce the BMS, it is necessary to establish a systematic and sustainable plan from the project promotion planning stage and take the leading role of decision makers to implement it. In order to introduce the BMS in large and small cities in developing countries, a master plan for public transportation, including buses and railroads, is required. As mentioned earlier, the BMS can improve the problems of direct buses by utilizing ICT technology, but along with other public transportation policies and plans such as urban railways, bus lanes or BRT, and integrated fare and semi-public systems. When such conditions and possibilities are considered in-depth, the outcome will be positive.

Therefore, it is necessary to establish a comprehensive and systematic public transportation master plan and implement it in various stages. In addition, city governments will need to continuously and persistently consult with stakeholders and revise a systematic plan to lead the way of solving the public transportation problem successfully.

5.2 COMBINING POLICIES TO MAXIMIZE BMS EFFECTIVENESS

As explained above, bus services can be improved, and it will ultimately contribute to achieve the goal of mitigating traffic congestion.
In order to maximize the effectiveness of the BMS, various policies such as the BRT, bus route adjustment and dedicated lanes, signal system and geometry improvement, bus lane control system,

electronic payment, and integrated fare system will be combined to achieve the effect. In the long term, it can evolve into a more efficient transportation system when it develops into an integrated traffic management form through the establishment of additional ITS such as electronic payment systems, enforcement systems, and traffic situation monitoring.

In order to reform the bus service, it is necessary for bus companies in the private sector to serve the public interest not only their own profits. To this end, Seoul and Daejeon adopted quasi-public bus systems to manage bus operation and bus drivers efficiently by jointly managing bus operation revenues, by giving subsidy to make up for loss of the bus company which operates on non-profitable routes, and by introducing a bidding system on the bus routes.

However, cities in the LAC and the Caribbean region with weak financial independence may face financial problems due to subsidies that should be increased each year. Based on the cost of the bus operation, the customer demand, route and fare policy should be carefully analyzed and introduced in advance.

5.3 SAVING BUDGE BY ADOPTING NEW TECHNOLOGIES AND PROVISION OF FINANCING PLAN

As discussed so far, the BMS is a viable alternative to solve the traffic congestion in cities of Latin America with minimum budget since it is one of the most cost-effective services among various ITS services. However, the BMS implementation still requires a certain amount of budget to implement in-vehicle devices for the bus and the BIT at the bus stations and the center for operation and maintenance, which can be a burden on the cities in Latin America that are already suffering from budget shortages. Therefore, new technologies including Quick Response code (QR code), smart phone, and Cloud Computing should be also considered as alternatives for data collection, processing, and provision when implementing the BMS with the purpose of cost saving.

In other words, it is expected that the budget for building and maintaining the BMS will be drastically reduced if real-time bus data is collected using the bus passengers' smartphones or QR codes rather the GPS, and if the neighboring cities can share a BMS center by using Cloud Computing rather than by building BMS centers in individual cities.

While the implementation of the BMS is significantly economical than the construction of a new metro, it can be a burden to build a BMS in the cities of many LAC and the Caribbean region, which are developing countries, especially if the BRT and electronic payment system are considered as well to maximize the outcome. Therefore, in pursuing the BMS project, the financing plan should be thoroughly reviewed through careful business feasibility analysis on the business promotion method.

In South Korea, as in the case of special accounting for transportation facilities, the Korean government can manage to finance through special accounts, but if the initial investments cannot be initiated by the government for economic reasons, loans and the Public Private Partnership (PPP) can also be considered. In the case of BMS, when combined with electronic payment, various business models, such as settlement fees and charging fees, can be adopted, which can be promoted in various forms, such as Build Operate Transfer (BOT) or Build Transfer Lease (BTL). In addition, BMS should also consider the cost of operation and maintenance in addition to the initial investment cost.

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