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Evaluation on Effectiveness of Intelligent Transport Systems in Suwon

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요 약

수원시는 2001년부터 2006년까지 도시 내 교통혼잡 완화를 위한 대안으로서 다양한 ITS 서비스를 도입하였다. 성공적인 ITS 시설 설치 후, 도입된 ITS 서비스에 대한 다양한 효과에 대하여 종합적으로 그리고 세부적으로 정량적·정성적 평가를 하려는 노력이 있었다. 그러한 노력의 일환으로서, 본 연구는 수원시에서 1단계 및 2단계 ITS 도입을 통하여 발생한 ITS 효과를 과학적이고 합리적인 방법으로 평가하고자 한다. 본 평가는 각종 현장 조사, 설문조사 그리고 경제성 평가를 통하여 수행되었다. 평가결과, 수원시 ITS 서비스 도입은 성공적이었다고 판단되었다. 하지만, 지속적인 유지관리 및 시설투자를 통하여 ITS 도입효과를 확대할 필요가 있는 것으로 사료된다.

Abstract

The city of Suwon has introduced various ITS services between 2001 and 2006 as an alternative to solve chronic traffic congestion in the city. After the successful implementation, there was an effort to evaluate effects from the ITS deployments. However, the effects caused from ITS implementations may be realized in many different ways. Therefore, this research effort was aimed at evaluating the effectiveness of ITS implements through the first and second phases in Suwon using reasonable and scientific methods. Based on results from the analysis of variables presenting traffic condition, surveys and economic evaluation, the implementation of ITS services in Suwon can be concluded successful. However, there is a need for efforts to maintain the effects produced from the successful introduction of ITS services through continuous upgrading the systems, intensive maintenance, and efficient operations.

Key words : ITS, evaluation, effectiveness, economic evaluation, traffic information system, bus information system

Ⅰ. Introduction

The majority of cities in Korea have suffered from chronic traffic congestion due to the dramatic economic development since the end of the 1980s. In order to mitigate the traffic congestion, various efforts, including providing more transportation facilities or improving the efficiency of existing transportation

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systems, have been conducted through the entire country. However, it is true that there are apparent limitations in providing more transportation facilities due to constrained resources such as insufficient budgets and right of way. As a result, the interest in Intelligent Transport Systems (ITS) has been increasing because it is considered as an merging alternative to solve current issues related to transportation by improving traffic mobility and safety through state of the art technologies for acquiring data, processing data and providing information.

The city of Suwon has had also a similar interest in ITS. Thus, Suwon has established an ITS master plan for completing ITS services through a few phases. Suwon has already completed the first phase and been operating a traffic information center that managed transportation at limited part of the city. And, in 2006, it has finished the second phase where the coverage of ITS services was expanded to the entire city.

The effects caused from ITS implementations may be realized in many different ways. Generally the effects may be divided into direct effects, including reductions of travel times and travel costs to users and operation costs to the city, and indirect effects which may influence to unspecified individuals such as changes in the quality of life. Therefore, this research effort was aimed at evaluating the effectiveness of ITS implements through the first and second phases in Suwon using reasonable and scientific methods. In addition, this research effort summarizes prior evaluation studies related to the evaluation of ITS effects in order to find a suitable evaluation measures for Suwon.

Ⅱ. Literature review

1. Background

The introduction of ITS in Korea was able to begin due to the efforts of the presidential SOC (social overhead capital) Investment Task Force Team in 1993. The actual initiation of ITS introduction was started by the Ministry of Construction and Transportation (MOCT), former Ministry of Land, Transport, and Maritime Affairs. MOCT established the national ITS master plan, and then legislated the Transport System Efficiency Promotion Act in 1999. In 2000, the government prepared for the national ITS master plan 21 which divided ITS into seven service areas, eighteen services, and sixty two unit services. The national ITS master plan 21 may be the most essential plan for ITS in Korea so far. The plan provides the structure of all ITS services and systems available for transportation user groups and a fundamental framework to realize the ITS services [1].

On the basis of the national ITS master plan 21, various ITS services have been successfully introduced in many metropolitan areas including Seoul and Busan as well as small and medium-sized cities including Suwon. As a result, 39 cities among entire 84 cites in Korea were operating some ITS services in 2008 [2].

2. Prior Studies

Two prior studies were considered as essential evaluation studies for ITS implements for the city; the evaluation study for ITS pilot project in Gwacheon and the effect analysis study for the construction of advanced transportation model cities [3-4]. The ITS pilot project in Gwacheon may be the first large-scale ITS implementation project for the city in Korea. The construction of advanced transportation model cities was initiated by MOCT to provide a substantial framework or model for ITS implementations to local governments on the purpose to promote the introduction of ITS through entire country. The evaluation study for ITS pilot project in Gwacheon can be divided into the performance evaluation of each system in the project and effect analysis using

the before and after study on measures of effectiveness (MOE) that were carefully selected to examine the comprehensive effects of the entire system. The part of the evaluation using the before and after study was intended to understand the changes in traffic condition just before and after the implementations, and the level of consciousness of citizen on ITS services. The part can be divided into a qualitative evaluation using surveys and a quantitative evaluation through field measurements. The items used for the qualitative and quantitative evaluations and their scales are presented in Table 1. The effect analysis study for the construction of advanced transportation model cities conducted qualitative and quantitative evaluations on the effectiveness and efficiency of the systems using a survey on traffic condition, inquiry of the database for a center, economic evaluation, and so on. The three cities under the evaluation used the identical MOEs so that all kinds of field data collections and surveys were conducted according the selected MOEs. The following items in Table 2 were applied to measure the effectiveness and efficiency of each system. It is noted that this research used a simulation model to acquire some MOEs as notified in Table 2. The research team searched some foreign studies for ITS evaluation studies. The research team found many prior studies in the cases of Japan and the U.S. The prior studies paid careful attention on selecting objective MOEs, and evaluation methodologies in order to estimate the effectiveness and efficiency of ITS implementations under evaluation in a reasonable and acceptable way. This effort is similar to what was done in Korea. One different thing is a continuous monitoring on the ITS implementations under evaluation. Even though before-and-after studies were adopted for the evaluation in general, many evaluation

〈Table 1〉 Evaluation items for the before and after study
〈표 1〉 사전·사후 평가를 위한 평가 항목들

System	Quantitative Evaluation		Qualitative Evaluation		Remark
	Items Measured	MOEs	Items Measured	MOEs	
Intersection Traffic Control System(I)	Traffic condition variables	Traffic volume Delay	Survey	Effectiveness and efficiency	Before & After
	Speed	Link speed Corridor speed			
Intersection Traffic Control System (II)	Traffic condition variables	Travel speed Queue length Degree of saturation	-	-	After
Bus Information System	Bus demand	Number of riders	Survey	Satisfaction Effectiveness and efficiency	Before & After
Parking Information System	Parking demand	Number of parking cars	Survey	Satisfaction Effectiveness and efficiency	Before & After
Electronic Toll Collection System	-	-	Survey	-	Before & After
Automatic Enforcement System	Accident and casualty	Number of accidents Number of casualty	Survey	Satisfaction Effectiveness and efficiency	After
Other Systems	-	-	Survey	Satisfaction Effectiveness and efficiency	After

Source: The Korea Transport Development Institute, “The final report of the evaluation study for ITS pilot project in Gwacheon,” 1998.

〈Table 2〉 Selected MOEs for each system and evaluation methods
〈표 2〉 시스템별 및 평가 방법별 선정된 성과지표

Systems	MOEs	Quantitative Evaluation		Qualitative Evaluation
		Field Data Collection	Simulation Analysis	Survey
Real-time Traffic Signal Control System	Traffic Volume	○	○	-
	Delay	○	○	-
	Average speed and travel time by links	○	○	-
	User satisfaction on the system	-	-	○
Traffic Information System for Urban Arterials	Average speed and travel time by links	○	○	-
	Delay by links	○	○	-
	User satisfaction on VMS Accuracy of information	-	-	○
Advanced Incident Management System for Urban Arterials	Processing time for accidents User satisfaction on the action of the subject authority	-	-	○
Automatic Enforcement System	Number of deaths and injured	○	○	-
Traffic Information System	Average speed and travel time by links	○	○	-
	Ratio of modal shift	○	○	○
	Delay on link travel	○	○	-
	Accuracy and satisfaction on information	-	-	○
Bus Information/ Management System	schedule adherence (Variation of estimated arrival times)	○	-	-
	Bus rider	-	-	
	Bus traffic	○	-	-
	Credibility and satisfaction on information	-	-	○
	Ratio of modal shift	-	-	○
Dedicated Bus Lane Management System	Section-averaged number of illegal parking	○	-	-
	Average travel time on the dedicated bus lanes	○	-	-
	User satisfaction	-	-	○

Source: The Ministry of Construction and Transportation, “Effect analysis study for the construction of advanced transportation model cities,” 2004.

studies had a monitoring system in each step for quality control. Some studies developed different MOEs, or benefits and costs in the case of cost-benefit analysis in each step, which were used for short-term, mid-term and long-term evaluations, separately. This way may consider the fact that the effect of ITS implementations may turn on in a different way or scale as time goes on. Finally, the effects and costs of individual ITS projects were well stored in a database and open to the public, especially in the U.S. Such a database may be beneficial to authorities who want to introduce ITS services but do not have enough experience. In 2005, MOCT has established the Implementation Guideline for ITS, which identified the methodologies to evaluation of ITS effectiveness as well as the general process

required to implement various types of ITS for the first time. In the chapter 8, the guideline specified spacial and temporal scopes, and details on the field survey and methodology necessary for evaluating the effectiveness of ITS. However, the guideline did not designate specific MOEs for the evaluation [5].

Ⅲ. Effectiveness of ITS

1. ITS Implementation in Suwon

The introduction of ITS in Suwon was initiated in 1997 through the project of the basic survey and design development for traffic information/ management center in Suwon. After finishing the detailed design for the construction of the traffic information center in Suwon, the first stage of ITS implementation and operation began in the format of a pilot project in 2001. The implementations for the first stage include a center system, traffic control systems at fifty critical intersections, seven variable message signs, seven CCTVs, two KIOSKs, and so on. Through the second stage, ITS services were expanded through the entire Suwon. The implementations for the second stage consists of an upgraded center system, traffic data collection systems, including loop detectors for traffic control and arterial data collection, Automated Vehicle Identification Systems, and CCTVs, Traffic Information Systems, including VMSs(variable message sign) for text, VMSs for movie, and World Wide Web, traffic signal control system, Bus Information System, mobile and stationary Parking Violation Enforcement Systems, and so on. Table 3 now summarizes the list of systems built in Suwon through the first and second stages [6].

2. Effect of ITS Implementation

This chapter provides the results of the before and after study on the effectiveness of ITS introduction in Suwon. The before and after study can be divided into a qualitative evaluation and a quantitative evaluation based on the type of analysis, and into field data

〈Table 3〉 ITS implementation in Suwon
〈표 3〉 수원시에 설치된 ITS

Systems	Sub-systems	No. of Implements	Stages	
			Stage I	Stage II
Center System, including World Wide Web	House for the Traffic information center and equipments	1	1	Upgrade and expansion
Traffic Data Collection Systems	Detectors	1,427	237	1,190
	AVIs	25	-	25
	CCTVs	34	7	27
Traffic Information Systems	VMSs	19	7	12
	World Wide Web	1	-	1
Bus Information Systems	On-board units	181	-	181
	Bus information terminals & KIOSKs	7	-	7
Real-time Traffic Signal Control Systems	Traffic signal controllers and detection systems	240	50	190
Parking Violation Enforcement Systems	Stationary parking violation enforcement systems	20	-	20
	Mobile parking violation enforcement equipments	20	-	20

collection, literature and statistics review, and surveys according to the method utilized. The before and after study first provided quantitative MOEs to estimate analysis results, and then the process for the objectiveness of the results was conducted in this research. The qualitative part like user satisfaction was analyzed via surveys. In addition, this research effort applied simulation models like EMME/2 and the ITS Deployment Analysis System (IDAS) in order to obtain the changes in traffic condition due to the introduction of ITS. The predicted traffic conditions such as traffic volume changes was used as an input data for economic analysis which was applied to investigate the economic feasibility of the ITS implementations in Suwon.

1) MOEs Selected for the Before and After Study

MOEs for the before and after study should be selected through an in-depth consideration about the impact on traffic conditions of each ITS service as well

〈Table 4〉 MOEs for each system
〈표 4〉 각 시스템별 성과지표

Systems	MOEs		Data Collection Methods
Traffic Information System	Quantitative Evaluation	Average Travel Speed by Links Travel time	Field data collection
	Qualitative Evaluation	Awareness Usage Satisfaction Necessity Appropriacy of the locations implemented	Survey
Bus Information System	Quantitative Evaluation	Bus headway	Field data collection
	Qualitative Evaluation	Awareness, Usage Satisfaction Necessity	Survey
Real-time Traffic Signal Control System	Quantitative Evaluation	Traffic Volume Delay Average Travel Speed by Links Travel time Queue length The number of injured The number of deaths	Field data collection Literature review
	Qualitative Evaluation	Awareness, Satisfaction Necessity	Survey
Parking Violation Enforcement System	Quantitative Evaluation	Change in the number of illegal parking	Literature review
	Qualitative Evaluation	Awareness Usage Satisfaction Necessity	Survey
World Wide Web	Qualitative Evaluation	Awareness Usage Satisfaction Necessity	Survey

as the entire ITS services such that the MOEs is able to estimate the degree of true changes in traffic conditions.

For the selection of MOEs, the research team has first examined prior studies in Korea, including the evaluation study for ITS pilot project in Gwacheon and the effect analysis study for the construction of advanced transportation model cities, as well as cases of other advanced countries. This was because the Implementation Guideline for ITS established in 2005 did not designate specific MOEs for evaluating the effectiveness of ITS. Due to the difficulties mentioned above, the research team specially paid lots of attention to selecting MOEs, which should represent substantial changes in traffic mobility, efficiency and satisfaction. Fortunately, the current version of the guideline provides more specific and practical MOEs for the evaluation [7].

The following table summarizes finally selected MOEs to be analyzed and those data collection methods for the evaluation of impacts of each system on traffic condition.

2) Analysis of Traffic Condition before and after Implementations

This research effort surveyed actual delays, speeds, travel times, and so on in 2006 for the analysis of changes in traffic condition before and after ITS implementations [6]. It should be noted that only a few distinct MOEs will be presented in this section thanks to the limitation of paper length

This research effort utilized the delay data presented in the mid-term transportation plan completed in 2001. For the data after the implementation, the traffic condition were separately collected under two different traffic signal operation modes, including time-of-day (TOD) mode and traffic responsive control (TRC) mode, because the selection of the two traffic signal control mode influence a lot on resulting traffic condition in signalized urban arterials. This is noted that only TOD mode was available in 2001. And, the TRC mode is the most essential feature of the Real-time Traffic Signal Control System applied in Suwon. The intersection average delay measured during peak hours under TOD mode shows 187.5 seconds per vehicle, which is about 39.9 percent reduction in delays compared with 311.9 seconds per vehicle, measured in the project for the mid-term transportation plan. The intersection average delay measured under TRC mode shows 179.9 seconds per vehicle, which is about 42.3 percent reduction in delays compared with 311.9 seconds per vehicle. This result makes sure that there was positive effect of ITS implementations, especially the Real-time Traffic Signal Control System, which may be the most effective alternative to mitigate traffic congestion.

In the case of speed analysis, this research effort utilized the data collected in the project for ITS master plan conducted in 2003. The data after the implementations of ITS services were separately collected under the two modes. The average travel speed shows 6 percent improvement from 37.10km/h in 2003 to 39.2km/ under TOD mode. Under TRC mode, the average travel speed of 44.27km/h turns out 19 percent improvement.

The schedule adherence of buses was analyzed to investigate the improvement of bus systems after the implementation of the Bus Information/Management System. The schedule adherence was represented using the coefficient of variation of bus headways measured. As the calculated coefficient of variation approaches to zero, the schedule adherence becomes higher.

$$C\nu = \frac{S_{\bar{h}}}{\bar{h}} \tag{1}$$

where,

$C\nu$ = coefficient of variation of bus headways,

$S_{\bar{h}} = \sqrt{\sum_{i=2}^{N} \frac{(h_i - \bar{h})^2}{N-2}}$ = Sample standard

deviation of bus headways,

$\overline{h} = \frac{1}{N-1}\sum_{i=2}^{N} h_i$ = Average of bus headways,

N = The number of measurements,

h_i = The bus headway measured in the i-th bus

The coefficients of variation in bus headways before and after the implementation of the Bus Information/Management System changed from 0.519 to 0.482, which means that the bus schedule adherence was improved in average.

Even though the enforcement records of illegal parking before and after the implementation of the Parking Violation Enforcement System were compared, there were no substantial changes in the numbers of enforcement records before and after the implementations in general through the entire city. However, there was a jump in the numbers of enforcement records at the sites where the systems were implemented. In addition, the numbers of enforcement records at the sites have been decreasing due to the awareness of the system, as times go on.

The improvement of safety after the introduction of ITS was recognized in many ITS evaluation projects. Unfortunately, however, the number of accidents, injured and deaths were not compared in the before and after study because this research was completed before the publication of related traffic accident statistics.

3) Results of Survey

This section was intended to present the qualitative effect of ITS implementations through survey targeting the citizen in Suwon. The items surveyed may be divided into three parts including the awareness on ITS services, user satisfactions on the entire ITS services and each ITS service, actual usages, and so on. The questionnaire used in the survey was made out by adjusting those used in other ITS evaluation projects after thorough consideration on the characteristics of the ITS services applied in Suwon. The total of 1,274 persons including 624 passenger car and taxi drivers, 510 bus rider, 124 bus drivers, 16 bus operators cooperated in the survey.

In the case of the awareness of citizen, 87 percent out of 1,274 persons answered that they already knew the implementations of ITS services in Suwon. In detail the workers in the transportation industry like taxi and bus drivers, who might use ITS services more frequently than normal citizen, knew ITS better. 93 percent of them answered that they already knew the implementation. However, 19 percent of passenger car drivers and 28 percent of bus riders answered that they did not aware of any ITS services at all.

For the question on the change in travel speed in arterials where ITS services were introduced, 41 percent answered ‘light improvement’ and another 41 percent answered ‘no improvement’ on the same question. In details, 4 percent and 35 percent of passenger car drivers answered ‘great improvement’ and ‘light improvement,’ respectively. On the contrary, 13 and 53 percent of taxi drivers answered ‘great improvement’ and ‘light improvement,’ respectively. Generally, workers in the transportation industry better aware the improvements of traffic speeds in main arterials.

For the question on the change in traffic safety in general, the majority of surveyees answered ‘no improvement.’ Therefore, it can be thought that the users are hard to aware directly the effect of ITS services on the improvement in traffic safety because the current ITS services were mainly focusing on the management of traffic flow and the supply of traffic information.

For the question on the usability of the traffic information provided from ITS services, 15 and 30 percent of surveyees answered ‘very useful’ and ‘some useful,’ respectively. In general, the majority of surveyees think that the information is useful.

For the question on the accuracy and availability of

〈Table 5〉 Preference of ITS services after implementation
〈표 5〉 ITS 서비스 설치 후 선호도 조사 결과

Type	Traffic Information System	Bus Information System	Real-time Traffic Signal Control System	Parking Violation Enforcement System	World Wide Web
Percentage	24%	23%	22%	16%	15%

traffic information provided, 81 percent of surveyees represented positive answers. In details, on the same question, the percentage of passenger car drivers who represented negative answers was higher than that of workers in the transportation industry like bus and taxi drivers. This means that bus and taxi drivers who have more opportunity to use the traffic information utilized the information better.

For the question on the necessity for expanding ITS services, the majority of surveyees presented positive answers where the 54 percent of answers was 'very necessary.' Based on the result, it can be concluded that the majority of citizen required more ITS services.

In addition, the research team asked to all surveyees, i.e., 1,274 persons, the most useful system among the ITS serviced installed in Suwon. As a result, the Traffic Information System was recognized as the most useful system through the surveyees. The Real-time Traffic Signal Control System, Parking Violation Enforcement System, and World Wide Web for traffic information followed the Traffic Information System as shown in Table 5.

4) Result of Economic Evaluation

The economic analysis is the whole process to estimate and compare all kinds of benefits and costs caused from the subject project in order to evaluate the economic feasibility of the project in a systematic way. As an evaluation method, this research effort applied the cost-benefit analysis method because the method is known the appropriate method for public works. In addition, the method is able to provide an obvious value which can be easily compared with other alternatives. In addition, it is easy to understand because all benefits and costs are often expressed in money terms, and are adjusted for the time value of money. It should be noted that the discount rate for the public works in Korea range between 5 through 10 percent. This research efforts applied 7.5 percent in this evaluation according to the Guidelines for Pre-feasibility Study on Transportation Projects [8], which is the most authoritative reference used for feasibility analyses in Korea. The cost for the feasibility analysis is the expenditure directly invested for the project. The cost can be divided into fixed costs, including the costs for design, construction, and installation, and variable costs, including costs for operations and maintenances. The benefit can be categorized as direct benefits and indirect benefits. However, actual items representing the direct and indirect benefit have generated a lot of controversy. This research effort applied only direct benefits including travel time saving, vehicle operation cost saving, and reductions of traffic accidents, emissions and noise according to the Guidelines for Pre-feasibility Study on Transportation Projects [8].

For the actual analysis, this research effort applied IDAS, which is a sketch-level ITS analysis tool that is designed to measure various ITS benefits and costs based on transportation planning model and three major resources–default ITS impact settings, the IDAS Equipment Database Spreadsheet, and the ITS Library for benefit measures [9]. In order to estimate user benefit in IDAS, the transportation demand data are necessary. Therefore, this research effort built the input data for IDAS using EMME/2, which is the most common transportation demand model in Korea

and the Origin-Destination tables and networks provided by the Korea Transport database [10].

The selection of analysis time period is very important in the cost-benefit analysis because benefits and costs expressed in money terms are adjusted for the time value of money through the entire analysis time period. Thus, all flows of benefits and flows of costs over the analysis time period are expressed on a common basis referred as present value. The research effort set the base year as 2004 and applied the analysis time period as ten years, which is less than that for normal transportation projects such as road constructions. This is because the economic life expectancy of facilities for ITS services is relatively short. Finally, all flows of benefits and flows of costs through 2004 and 2014 were compared using the cost-benefit ratio (CBR) and internal rate of return (IRR). The analysis result showed 5.12 in CBR, 98.77% in IRR. Conclusively, the ITS services turned out economically feasible.

Ⅳ. Conclusions

In the analysis of traffic condition before and after the implementations, variables representing traffic condition such as delay, travel speed, bus schedule adherence, etc. were relatively improved after the implementations of ITS services. However, such effects may be generated from other efforts, including upgrades of existing road networks and constructions of detour roads, traffic system management (TSM) projects as well as the introduction of ITS services. It is technically difficult to extract the pure effects generated from only the introduction of ITS services, which is the common limitation in many ITS evaluation studies.

The survey results, including the awareness of citizen on ITS and high degree of user satisfaction can be an essential evidence for the positive effects from ITS implementation. It was found that users prefer to the ITS services which they can actually use and get benefits from. Such ITS services include the Traffic Information System and Bus Information System. Such findings through the survey may be utilized as a basic data in the future decision making process for long-term ITS deployment plan. In addition, the economic analysis results in terms of CBR and IRR showed the positive feasibility of the ITS deployments through the stages 1 and 2.

Based on the above results, the implementation of ITS services in Suwon can be concluded successful. However, there is a need for efforts to maintain the effects produced from the successful introduction of ITS services through continuous upgrading the systems, intensive maintenance, and efficient operations.

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