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The Accuracy Levels of Vehicle Detectors Commonly Used in Korea Based on the Results of Quality Certification Test

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Abstract: The Ministry of Land, Infrastructure and Transport of Korea introduced the ITS system performance evaluation about six and a half years ago. The main purpose is to make sure that accurate and reliable real-time traffic data are collected from the ITS system installed. There are three types of performance evaluations, which are Quality Certification Test, Pre-Delivery Test and Periodic Check in Operation. In this paper the accuracy levels of vehicle detectors commonly used in Korea are analyzed based on the results of quality certification tests conducted during 2008-2012. The test items consist of volume, speed and occupancy. The analysis shows that loop detectors have the best levels of accuracy in all three test items and their levels of accuracy have been steady. Video image detectors do not have so good levels of accuracy as loop detectors, but the levels of accuracy have improved as time passes. Radar detectors do not have good levels of accuracy. However, their levels of accuracy have improved as time passes. The last vehicle detectors, geomagnetism detectors have the worst accuracy in the occupancy item.

Key words: Performance evaluation, accuracy level, vehicle detector, quality certification test.

1. Need for and Types of the ITS System Performance Evaluation

In Korea ITS systems such as vehicle detectors, automatic vehicle identifiers, CCTVs, VMSs, etc. have been built over the national expressway and highway networks for the last fifteen years. The purpose is to solve or ease severe traffic congestion problems caused by the rapid increase of automobiles by providing real-time traffic information to vehicle drivers. According to the Statistics Korea [1] and the Ministry of Land, Infrastructure and Transport of Korea [2], the number of automobiles registered has increased from 10,413,427 vehicles in 1997 to 18,437,373 vehicles in 2002. The annual increase rate is 4.16%. However, the total length of road has increased in the rate of 1.59% annually for the same period.

In order to provide reliable real-time traffic information, it is necessary to collect traffic data with a certain level of accuracy from the ITS system installed. To make sure that accurate data are collected, the first and most important step is to select the ITS system which can produce traffic data with a certain level of accuracy. For this purpose, the quality of the system needs to be tested before it is selected for installation. This is referred to as the quality certification test.

After the system is selected, it will be installed in the designated site. However, the site may have a different traffic environment from the site where the quality certification test was conducted. Thus, the system installed in the designated site needs to be tested and calibrated before it is delivered to the ITS system investor. This second step is referred to as the pre-delivery test.

Even though the newly installed ITS system can function well for some time period, it is destined to function at a lower level and thus produce inaccurate traffic data, if it is not maintained properly. It is the

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reason why the system needs to be checked and calibrated periodically. This third step is referred to as the periodic check in operation.

The above-mentioned three steps, quality certification test, pre-delivery test and periodic check in operation, are referred to as ITS system performance evaluation in this paper to distinguish them from simple test or check. The last two steps, pre-delivery test and periodic check in operation, had been introduced in the previous paper [3]. Thus, in this paper the details of the quality certification test will be introduced and the accuracy levels of vehicle detectors, which are commonly used in Korea, will be analyzed based on the results of quality certification tests conducted during 2008-2012. The items for the quality certification test consist of volume, speed and occupancy.

This paper includes the following contents:

- Historical background of the quality certification test
- ITS systems subjected to the quality certification test
- Term of validity of the quality certification test
- Criteria and Methodologies for the quality certification test
- Types of vehicle detectors commonly used in Korea
  - Inductive loop detector
  - Video image detector
  - Radar detector
  - Geomagnetism detector
- Accuracy levels of vehicle detectors based on results of the quality certification tests
  - Inductive loop detector
  - Video image detector
  - Radar detector
  - Geomagnetism detector

2. Historical Background of the Quality Certification Test

Before proceeding with our discussion further, it should be mentioned that the Ministry of Construction and Transportation, the Ministry of Land, Transport and Maritime Affairs and the Ministry of Land, Infrastructure and Transport are the same ministry. Only the name, not the function, has been changed together with the change of government. Thus, in this paper the Ministry of Land, Infrastructure and Transport (MLIT) of Korea, which is the latest name for the ministry, is consistently used to avoid the confusion of readers.

As mentioned in the previous section, the quality certification test is a category of ITS system performance evaluation and thus has the same historical background. Based on the previous study of Lee [3], it can be summarized as follows:

For the years 2001 - 2005 the Ministry of Land, Infrastructure and Transport (MLIT) funded several researches such as Development of the ITS System Performance Evaluation Framework, Development of the ITS System Performance Evaluation Methodology, etc. in order to establish the definition, methodology and process of ITS system performance evaluation.

In May of 2005MLIT designated the Korea Institute of Construction Technology (KICT), which is a government-supported research institute, as the exclusive organization for ITS system performance evaluation based on the 'National Transport System Efficiency Act'.

Based on the results of the researches done for the years 2001 – 2005, MLIT notified the 'Guidelines for ITS Building and Operation' in August of 2005. The Guidelines indicates that the term of validity of the quality certification test for ITS systems is two years. Also, it requires developing the portable reference equipment which will be used for performance evaluation of ITS systems installed [4]. The Guidelines was revised in 2009.

In May of 2006 MLIT notified the ‘Guidelines for ITS System Performance Evaluation’. The Guidelines includes the methodology, procedure and evaluation criteria for performance evaluation of vehicle detectors and automatic vehicle identifiers among various ITS systems [5]. The Guidelines was revised twice in 2008 and 2009.

In 2007 the performance of ITS systems such as vehicle detectors and automatic vehicle identifiers was evaluated for the first time.

In December of 2009 MLIT completely revised the ‘National Transport System Efficiency Act’ and named it the ‘National Integrated Transport System Efficiency Act’. In the act the article about ITS system performance evaluation was newly included [6].

In June of 2010 MLIT additionally designated Korea Expressway Corporation and ITS Korea as the exclusive organizations for ITS system performance evaluation. In October of 2010 MLIT notified the ‘Guidelines for ITS Project Implementation’. The Guidelines indicates that the performance of ITS system in operation must be evaluated every two years [7].

3. ITS Systems Subjected to the Quality Certification Test

According to Article 48 of the 'Guidelines for ITS Building and Operation' [4], both the site constituent devices such as vehicle detectors, automatic vehicle identifiers, VMSs, CCTVs, etc. and the system as a whole such as an ITS center built and operated for public purpose by a road authority or an ITS system investor are subjected to the ITS system performance evaluation.

However, due to technical and methodological limitations the ‘Guidelines for ITS System Performance Evaluation’ [5] indicates that the ITS systems which are subjected to the quality certification test are limited to vehicle detectors, automatic vehicle identifiers. Also, it includes the methodology, evaluation criteria and procedure for the quality certification test of vehicle detectors, automatic vehicle identifiers. For the last three years a couple of researches have been conducted with funding from MLIT to establish the methodology, evaluation criteria and procedure for the quality certification test of ITS system such as DSRC detector. However, the research results were not perfect enough to cover all the details necessary for establishing the evaluation criteria and methodology for the quality certification test of those ITS systems.

4. Term of Validity of the Quality Certification Test

The 'Guidelines for ITS Building and Operation' [4] indicates that the terms of validity of the quality certification test for ITS systems are two years for vehicle detectors and automatic vehicle identifiers. It means that the vehicle detectors and automatic vehicle identifiers should take the quality certification test every two years to become a candidate for selection by ITS system investors.

5. Criteria and Methodologies for the Quality Certification Test

The criteria and methodology for quality certification test of vehicle detectors and automatic vehicle identifiers are mentioned in Article 4-8 of the Guidelines for ITS System Performance Evaluation [5]. In Article 7the criteria and methodology for vehicle detectors are mentioned. In Article 8 those for automatic vehicle identifiers are mentioned.

5.1 Vehicle Detector

The evaluation items for vehicle detector are the volume, speed and occupancy. Here, the volume is calculated by summing up the total number of vehicles which pass the detection point/range during a certain time period, in this case 30 minutes. The speed is calculated by taking the arithmetic average of the average speed of vehicles which pass the detection point/range during analysis unit time interval, in this case 1 minute. The length of detection range is 3 meters. The occupancy is calculated by taking the arithmetic average of the proportion of time which the detection point/range is occupied by the vehicles passing it during analysis unit time interval, in this case 1 minute.

As the rating scale ‘100% − MAPE’ is used, where MAPE is the mean absolute percentage error and calculated as follows:

$$MAPE(\%) = \frac{\sum_{i=1}^{n} \frac{|X_i - Y_i|}{Y_i}}{n} \times 100$$

where X_i = average of the values collected by the target system at analysis unit time interval *i*

Y_i = average of the reference values collected by the reference equipment at unit analysis time interval *i*

n = no. of analysis unit time intervals

All the items are evaluated for all the lanes in a direction, unlike the pre-delivery test and periodic check in operation where the speed is evaluated only for the far-right lane due to the technological limitation of portable reference equipment.

The evaluations are conducted four times a day, i.e. at sunrise, daytime, at sunset and night-time, for three days within a week. The evaluation time length is 30 minutes for each. However, the evaluation time length should become longer when the volume is less than 100 vehicles.

Here, the sunrise means the time period between 15 minutes before and after the sunrise time forecasted by the Korean Meteorological Agency. The daytime means the time period between half an hour after sunrise and half an hour before sunset. The sunset means the time period between 15 minutes before and after the sunset time forecasted by the Korean Meteorological Agency. The night-time means the time period between half an hour after sunset and half an hour before sunrise. One minute is used as the analysis unit time interval.

5.2 Automatic Vehicle Identifiers

The evaluation item for automatic vehicle identifier is the vehicle number plate recognition rate. As the rating scale '100% − PE' is used. PE is the percentage error and calculated as follows:

$$PE(\%) = \frac{E}{Y} \times 100$$

where E = no. of vehicles whose number plate is misread or unread by the target system during the analysis unit time interval

Y = no. of vehicles whose number plate is read by the reference equipment during analysis unit time interval

The vehicle recognition rate is evaluated for all the lanes in a direction. Here, the evaluations are conducted four times a day, i.e. at sunrise, daytime, at sunset and night-time, for three days within a week. The evaluation time length is 30 minutes for each. However, the evaluation time length should become longer when the volume is less than 100 vehicles.

Here, the sunrise means the time period between 15 minutes before and after the sunrise time forecasted by the Korean Meteorological Agency. The daytime means the time period between half an hour after sunrise and half an hour before sunset. The sunset means the time period between 15 minutes before and after the sunset time forecasted by the Korean Meteorological Agency. The night-time means the time period between half an hour after sunset and half an hour before sunrise. Thirty minutes are used as the analysis unit time interval.

The methodologies and criteria for the quality certification test of vehicle detector and automatic vehicle identifier mentioned in this section are summarized in Tables 1 and 2. The 'target device' in the table means the system unit which receives the quality certification test. In this paper 'device' and 'system unit' are used interchangeably.

As shown in Table 2, the quality certification test does not provide the criteria such as pass and fail, unlike the pre-delivery test and periodic check in operation, but it provides the levels of accuracy such as excellent, good, average and below average for the target system. However, in almost all the cases ITS system investors require the possible best accuracy level such as Excellent for their candidate system.

Table 1 Methodologies for the quality certification test.

Classification	Vehicle Detector	Automatic Vehicle Identifier
Evaluation Items	Volume, speed, occupancy	recognition rate
Lanes Subjected to Evaluation	all lanes	
Equipment	Permanent Reference Equipment (for collecting reference values)	
Evaluation Time	• 30 min for sunrise, daytime, sunset and night-time • vehicle count ≥ 100	• 30 min for sunrise, daytime, sunset and night-time • vehicle count ≥ 100
	• 1-min-interval analysis	• 30-min-interval analysis
Rating Scale	100% - MAPE	100% - PE

Table 2 Criteria for the quality certification test.

Level of Accuracy	Rating Scale			
	Vehicle Detector			AVI
Evaluation Items	Volume	Speed	Occupancy	Recognition rate
Excellent	≧95 %			≧90 %
Good	≧90 %			≧80 %
Average	≧80 %			≧70 %
Below Average	<80 %			<70 %

6. Types of Vehicle Detectors Commonly used in Korea

In Korea inductive loop vehicle detectors, video image vehicle detectors, radar vehicle detectors and geomagnetism vehicle detectors are used. Among them loop detectors and video image detectors are most commonly used over the national expressway and highway networks.

In the beginning stage of introducing ITS systems in Korea, the inductive loop detectors were installed widely. The performance of inductive loop vehicle detector is not affected by the environmental conditions such as fog, snow, illumination intensity, etc. However, the inductive loop and lead buried under the road surface were broken frequently due to heavy vehicles, rain, snow, temperature and construction work, etc. Thus the video image vehicle detectors, which does not have to be buried under the surface of the road for the camera and controller are placed on the pole, began to be installed. Figure 1 shows the video image vehicle detector that is widely used over the national expressway and highway networks and Figure 2 shows the inductive loop vehicle detector. Figure 3 shows the automatic vehicle identifier that is widely used over the national highway networks.

7. The Facilities for Quality Certification Test

There are two facilities for quality certification test. One is located in Gonjiam in Kyunggi Province and the other in Ansan City in Kyunggi Province. The latter is not operational yet. Figure 4 shows the facilities.

8. Accuracy levels of vehicle detectors based on results of the quality certification tests

Tables 3-6 [8] show the accuracy levels of four types of vehicle detectors based on the results of quality certification tests conducted during 2008-2012. The test items consist of volume, speed and occupancy.

The results show that loop detectors have the best levels of accuracy in all three test items and their levels of accuracy have been steady. Video image detectors do not have so good levels of accuracy as loop detectors, but the levels of accuracy have improved as time passes. Radar detectors do not have good levels of accuracy. However, their levels of accuracy have improved as time passes. The last vehicle detectors, geomagnetism detectors have the worst accuracy in the occupancy item.

Fig. 1 Example of the video image vehicle detector used in Korea(Lee, 2013).

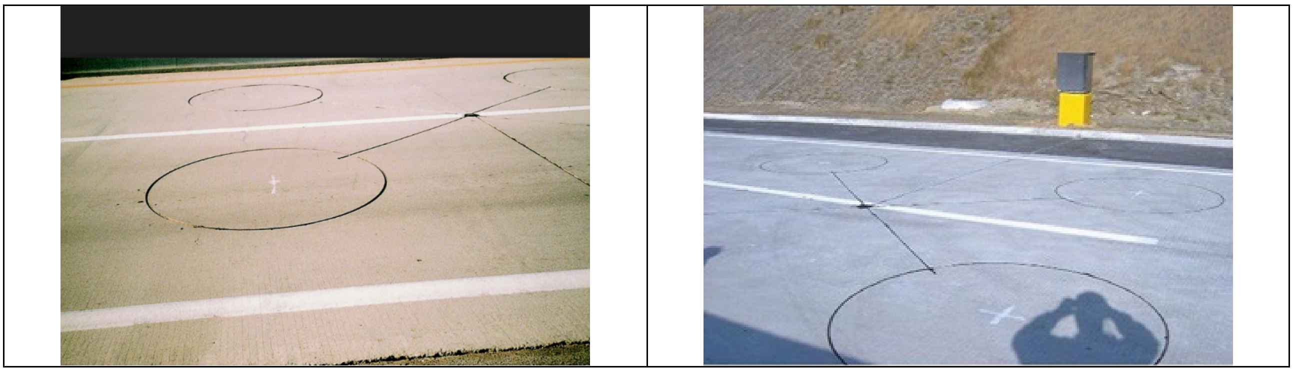

Fig. 2 Example of the inductive loop vehicle detector used in Korea (Lee, 2013).

Fig. 3 Example of the automatic vehicle identifier used in Korea.

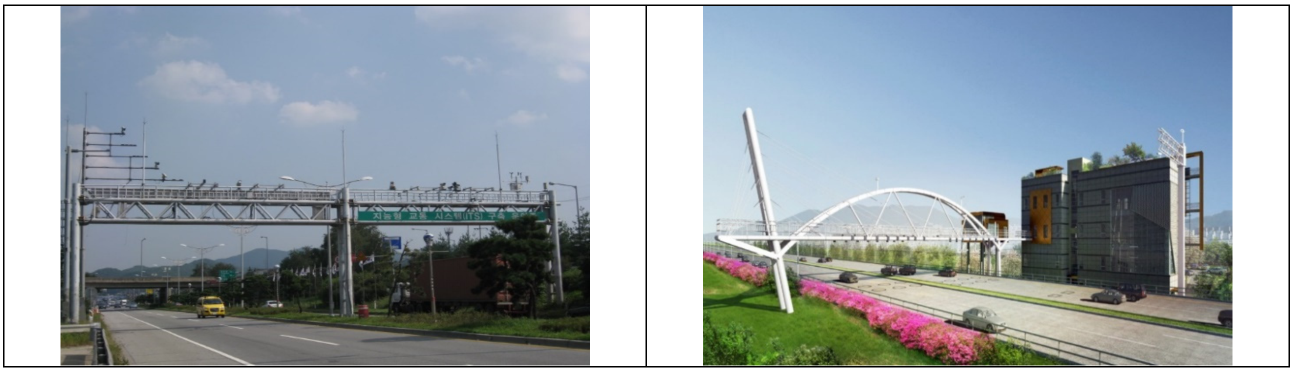

Fig. 4 Gonjiam (Left) and Ansan (Right) quality certification facilities.

Table 3 Inductive loop vehicle detector.

Year	Volume(%)	Speed(%)	Occupancy(%)
2009	98.8	98.5	96.0
2010	100.0	99.0	98.0
2011	99.3	98.7	97.7
2012	99.4	99.0	97.6

Table 4 Video image vehicle detector.

Year	Volume(%)	Speed(%)	Occupancy(%)
2008	93.0	96.3	87.7
2009	96.0	97.0	89.8
2010	96.0	96.3	92.0
2011	94.6	95.2	90.0
2012	95.0	97.0	90.0

Table 5 Radar detector.

Year	Volume(%)	Speed(%)	Occupancy(%)
2008	86.3	94.3	80.5
2009	94.0	93.0	91.0
2010	94.0	97.0	85.0
2011	96.0	94.0	92.0
2012	96.0	98.0	91.0

Table 6 Geomagnetism detector.

Year	Volume(%)	Speed(%)	Occupancy(%)
2011	94.5	88.8	78.3
2012	98.0	99.0	74.0

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