# Test-bed Design for Evaluation of Intelligent Transportation Systems and Intelligent Vehicle Systems

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*Abstract*— **As today's growing concern about the demand for vehicle's safety system, and especially about intelligent transportation systems (ITS) and intelligent vehicle systems (IVS), have aimed at better driving safety and efficient transportation to vehicle users. Many safety systems have been launched in the market several years ago. Therefore, it is important to evaluate the vehicle safety system. First of all, this paper describes in detail the concept of the test-bed. This test-bed is carefully designed to meet the requirements of ISO/TC204. This test-bed will be used to conduct testing on various intelligent control systems, such as adaptive cruise control system, lane departure warning system, cooperative intersection warning system as well as ABS and electronic stability control system, etc.**

*Keywords*— **Intelligent Transportation Systems, Intelligent Vehicle Systems, Proving Ground, Vehicle Test, Integrated Safety System.**

## I. Introduction

Recent developments in the automotive industry have aimed at better driving safety, traffic efficiency, and providing information to vehicle users. People spend more time in their vehicles than ever before. Advanced vehicle electronics have come into wide use not only in the automobile industry but also various other industries and our daily life. We seek to ensure safety, to develop measures to reduce dangerous situations that may lead to accidents, and to avoid accidents.

With a vehicle population of nearly 6.0 million in 2006 and one of the highest rates of traffic accidents, in Korea are becoming increasingly aware of the importance of vehicle safety. It is clear that the number of road fatalities and road accidents worldwide has been increasing rapidly, particularly in recent years. There are many different strategies for reducing and preventing accidents. It is likely to have serious commercial and financial consequences.

ITS and IVS provides tools that can assist us in addressing these problems as well as anticipate and address future demands through a strategic approach to transportation. Many vehicle safety systems have been launched in the market several years ago. ITS and IVS can benefits in terms of transport efficiency, sustainability, safety and security. The global market for ITS and IVS is projected to reach $18.5 billion (US) by 2015, according to new report by Global Industry Analysts Inc.

For evaluation of ITS and IVS, appropriate measurement and evaluation methods are necessary to evaluate and optimize the system functions under real road environment. However, currently, no appropriate test facilities exist and definitely faced several evaluation challenges. To overcome this imitation, is designed to create an ITS proving ground facility.

This paper is describes concepts for testing and evaluation of ITS and IVS. Requirements for an evaluation system to verify performance are also discussed.

## II. Concepts of Test-bed

In this section, we describe the concepts of test-bed, a brief overview of ITS proving ground and our testing and evaluation system.

### A. Explanation of the ITS and IVS

Vehicles of today offer an increasing number of ITS and IVS. Cruise control and route guidance are examples of systems already in frequent use, and lane departure warning, night vision and collision warning are examples of systems now coming into commercial use.

ACC and FSRA - ACC is an in-vehicle electronic system that maintain a set constant vehicle's speed to the traffic environment. FSRA is a system to extend the operation speed of acc to the full speed range and keep a distance with the vehicle running in front.

LDWS and LKAS – LDWS supports the driver to stay in his lane. The LKAS, just like LDWS, the assistant measures the vehicle position with respect to the lane, but offers active support in keeping the vehicle in the lane.

LCDAS is a system to give a warning of vehicles running in a blind spot or vehicles approaching from behind.

ITS and IVS can be classified into four types: Longitudinal, Lateral, co-operative Control system and other safety control system.

Type 1 of longitudinal control systems contains systems like Adaptive Cruise Control (ACC), Full Speed Range Adaptive Cruise Control System (FSRA), Low Speed

Following (LSF), Forward Vehicle Collision Warning Systems (FVCWS) and Forward Vehicle Collision Mitigation Systems (FVCMS), etc.

Type 2 of lateral control systems contains systems like Lane Departure Warning Systems (LDWS), Lane Changing Decision Aid System (LCDAS), Blind Spot Detection (BSD) and Lane Keeping Assist Systems (LKAS), etc.

Type 3 of co-operative control systems contains systems like Cooperative Intersection Signal Information and Violation Warning System (CISIVWS), Traffic Impediment Warning System (TIWS) based on Vehicle-to-Vehicle (V2V) and vehicle to infrastructure (V2I) communication.

Type 4 of other safety control systems contains systems like Roll Stability Control (RSC), Electronic Stability Control (ESC), Active Front-Lighting System (AFS), Maneuvering Aids for Low Speed Operation. (MALSO), Pedestrian Detection and Extended Range Backing Aid System (ERBA), etc. The table 1 summarizes the list of available test and test requirements.

**TABLE 1.** TEST TYPES AND REQUIREMENT

| Items | | Test Types and Requirements | Feasibility |
|---|---|---|---|
| Longitudinal Control | ACC, FERA, LSF, FVCWS, FVCMS | Liner test 110km/h, with 3lanes | O |
| | | Liner test 230km/h, with 3lanes | O |
| | | Curve test R125m, lengths 110m | O |
| | | Curve test R250m, lengths 168m | O |
| | | Curve test R500m, lengths 221m | O |
| Lateral Control | LDWS, LKS | Liner test 500m | O |
| | | Curve test R500m, lengths 400m | △ |
| | | Curve test R250m, lengths 306m | △ |
| | LCDAS, BSD | Liner test 1200m, with 3lanes | O |
| | | Curve test R125m, lengths 500m | △ |
| | | Curve test R250m, lengths 750m | △ |
| | | Curve test R500m, lengths 750m | △ |
| Cooperative Control | CISIVWS | Intersection test, with 2lanes | O |
| | TIWS | Curve test, , with 2lanes | O |
| Other Safety Control | RSC, ESC | Function test, Dynamic platform 100x25m | O |
| | AFS | Intersection test, with 2lanes | O |
| | | Curve test R125m, 250m, 500m | O |
| | | Tunnel test 70km/h, lengths 200m | O |
| | MALSO, ERBA | Function test, Dynamic platform 100x25m | O |

## *B. Descriptions of the Test-bed*

This section presents the overall architecture of the test-bed. The test-bed provides a suitable evaluation platform to test ITS and IVS that is designed for various performance evaluation test applications of integrated safety system.

When designing a proving ground having the highest possible neutral speed is always a priority. In addition, test-bed is required to comply with the minimum roadway radiuses 125, 250 and 500m for ITS (ACC, LDWS, etc) curve capability test. The structure of the test-bed is shown in Figure 1.

The test-bed includes the following tracks:

- ITS high speed circuit
- Cooperative vehicle-infra test intersections
- Special test track
- Test hills
- Multipurpose test track
- External noise test track
- Steering pad

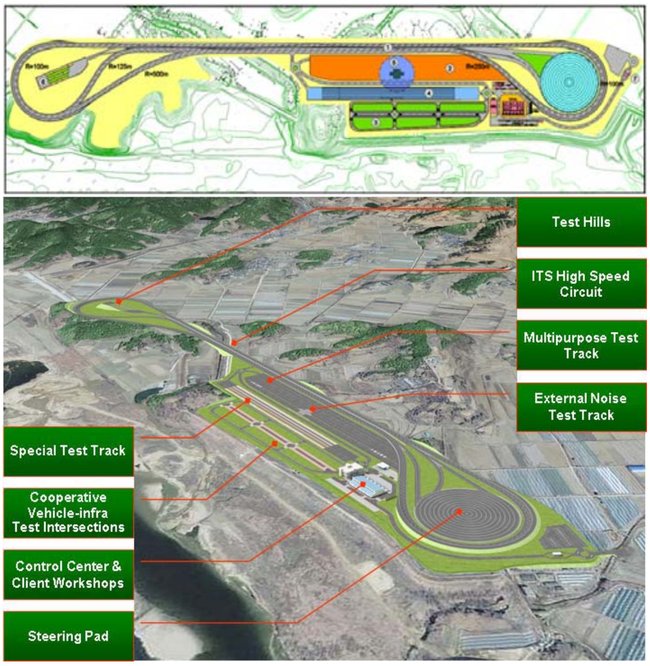


**Figure 1.** Layout of the test-bed

## *C. General Specification of ITS Proving Ground*

ITS proving ground offers various test tracks, ITS high speed circuit, cooperative vehicle-infra test intersections and special test tracks. The proving ground is spread across approximately 376,000 square meters in size. The table 2 shows general specification of the proving ground.

**TABLE 2.** SPECIFICATION OF THE PROVING GROUND

| Test Tracks | | Specification |
|---|---|---|
| ITS High Speed Circuit | | Total length of circuit: 3,681m<br>Number of lanes: 3 |
| Cooperative Vehicle-Infra Test Intersections | | 3Intersections,<br>Length 1,200m |
| Special Test Track | Belgian Road | Length:800m, width: 4m |
| | Washboard Road | Length: 182m, width: 4m |
| | Cobblestone Road | Length: 182m, width: 4m |
| | Twist Road | Length: 182m, width: 4m |
| | Rough Road | Length: 182m, width: 4m |
| | Salt Splash Shower Tunnel | Length: 50m, width: 4m |
| | Water Splash Shower Tunnel | Length: 120m, width: 6m |
| | Water Wade | Length: 60m, width: 4m |
| Multipurpose Test Track | | Length: 568m, width: 70m |
| External Noise Test Road | | Length: 40m, width: 4m |
| Test Hills | | Gradient 12%, 18%, 24% |
| Steering Pad | | Radius: 85m |

*1) ITS High Speed Track*: The total length is 3,681m, concrete surface. The high speed track has 3 lanes of test road. It mainly used for ITS and IVS Performance (ACC, LDWS, LKS, etc.)Test.

- Straights: length 1,360m, maximum speed 204km/h
- Bends: radius 100m, banking angle 30˚, neutral speed 111km/h

*2) Cooperative Vehicle-Infra Test Intersections:* The total length is 1,200m and has 3 intersections. It mainly used for pedestrian protection and intersection safety Test.

*3) Special Test Track*: The size of the area is approximately 490x35m, 4 lanes of test road. Including belgian road, washboard road, cobblestone road, water splash shower tunnel, etc. It mainly used for durability and reliability test.

In the case of the test tracks shown above, it is also possible to evaluate the vehicle dynamics and the external noise.

### *D. The Testing and Evaluation System*

ITS and IVS is requires vehicles to meet specific performance requirements. To verify the accuracy of the ITS and IVS, vehicle relative position, vehicle relative speed and vehicle dynamics was measured. ITS and IVS requires very high accuracy of the measured parameter, which is achieved using DAQ, inertial measurement, GPS technology.

The key factors of the testing and evaluation of overall system is the synchronization of data acquisition system (DAQ), inertial navigation system (INS), differential global positioning system (DGPS) and Non-contact optical sensors, etc. in real time. Figure 2 shows field testing and evaluation system for ITS and IVS.

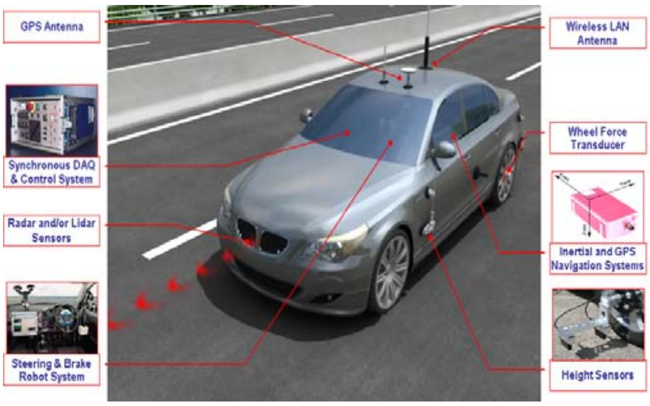


**Figure 2.** Configuration of evaluation system

The prmary goals of the testing were to collect data under real road environment. Moreover, this distance must be measured very precisely in order to obtain accurate results. By combination of DGPS and INS offers a complete platform for testing ITS and IVS. The position of the vehicle can be measured with up to 2cm position accuracy and speed measurements are accurate to 0.05km/h, which is essential for testing ITS and IVS.

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## III. TEST SCENARIOS

In the following some examples of scenarios and application are presented.

### *A. ACC System*

Automatically adjusts a car's speed to maintain a safe following distance to other vehicles. It uses forward-looking distance sensor to detect the speed and the distance of the vehicles ahead of it up to 200 meters. ACC system can automatically adjust speed by braking or accelerating in order to maintain a proper distance between vehicles in the same lane. Standard ACC systems are usually not operational below a certain speed threshold. The operational speed is between 30 and 200 Km/h for common system.

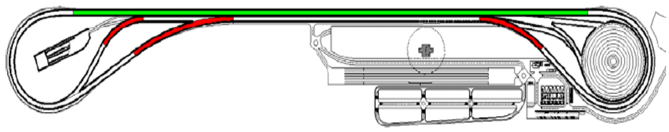

**Figure 3.** Example of ACC system

### *B. Cooperative System*

V2V technology enables vehicles to communicate with each other without driver involvement. V2V relies on wireless vehicle networking that enables the exchange of data such as location and speed. The system analyses this data instantly and can help to prevent accidents from happening by warning drivers early about potential danger from other vehicles.

V2I is the technology that enables vehicles to communicate with a communication system installed at the road side. The driver can obtain information about traffic jams, speed limitation, or dangers on the road.

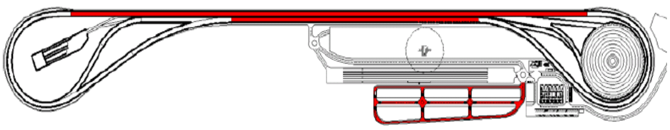

**Figure 4.** Example of cooperative system

### *C. Intersection Assistance System*

The system identifies potential collision targets in intersection scenarios detecting cars approaching. It informs driver through audible or visual alerts. The system can also pre-charge the braking system to provide full brake force as soon as the driver applies the brakes. The system warns the driver, but does not interact autonomously.

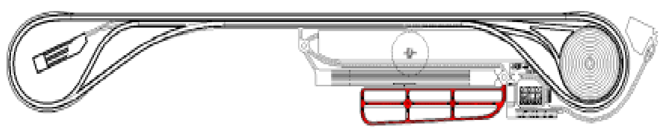

**Figure 5.** Example of intersection assitance system

### D. RSC System

Roll stability control systems take corrective action, such as throttle control or braking, when sensors detect that a vehicle is in a potential rollover situation. The functionality combines different systems such as ESC, AFS, and active roll bar in order to mitigate roll over scenarios.

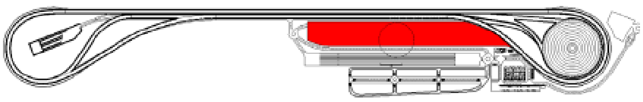

**Figure 6.** Example of RSC system

### E. Virtual Reality 3D Modelling

We also conduct a virtual reality 3D modelling, as shown in Figure 7. The benefits of using virtual reality 3D modelling are used to realize the various testing methodologies, mainly the test cases and the test execution environment.


**Figure 7.** Example of Virtueal Reality 3D Modeling

## IV. Conclusions

This paper introduced test-bed configurations of ITS and IVS. One of the key objectives for test-bed is the development of a suitable evaluation platform to test ITS and IVS. The test-bed provides on the state-of-the-art testing and evaluation solution for ITS and IVS that is designed for various vehicle test applications. Moreover, this test-bed is carefully designed to meet the requirements of ISO/TC204. This test-bed will be used to conduct testing on various intelligent control systems, such as ACC, LDWS, cooperative intersection warning system as well as ESC and RSC, etc. This test-bed will also be able to evaluate of infrastructure information and vehicle sensors data that will collect and transmit in real road environment.

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