DEVELOPMENT OF A DRIVING SIMULATOR FOR THE DRIVING PRECISION APTITUDE TEST

Jun-Hee Cho
CEO, Innosimulation, Inc.
Sangam-dong 1580, Mapo-gu, Seoul, Korea, e-mail: juni@innosim.com

Young-Sam Kim
Research Manager, Innosimulation, Inc.
Sangam-dong 1580, Mapo-gu, Seoul, Korea, e-mail: yskim@innosim.com

Young-Woo Sohn
Professor, Department of Psychology, Yonsei University
Seongsanno 262, Seodaemun-gu, Seoul, Korea, e-mail: yssohn@yonsei.ac.kr

Jae-Yeong Kwon
Senior Researcher, Korea Transportation Safety Authority
523 Gojan-dong, Danwon-gu, Ansan-si, Gyeonggi-do, Korea, e-mail: skida04@ts2020.kr

Su-Ae Park
Senior Researcher, Institute of Human Behavior, Yonsei University
Seongsanno 262, Seodaemun-gu, Seoul, Korea, e-mail: parksuae@gmail.com

Kyung-Soo Lee
Senior Researcher, Institute of Human Behavior, Yonsei University
Seongsanno 262, Seodaemun-gu, Seoul, Korea, e-mail: klee@yonsei.ac.kr

Eung-Kyung Chung
Senior Researcher, Institute of Human Behavior, Yonsei University
Seongsanno 262, Seodaemun-gu, Seoul, Korea, e-mail: etopaz@hanmail.net

Hyun-Kuk Sohn
Researcher, Institute of Human Behavior, Yonsei University
Seongsanno 262, Seodaemun-gu, Seoul, Korea, e-mail: coexistence55555@gmail.com

ABSTRACT

The driving precision aptitude test is conducted by the Korea Transportation Safety Authority (TSA) to determine the qualification and aptitude of commercial vehicle drivers. The test consists of the personality test, driving tendency classification test, driving hazard perception test and situation awareness perception test. All items are tested on the simulator platform. The driving simulator for the driving precision aptitude test has a driver's seat cabin system that was made of the actual quadrant vehicle, a 32-inch LCD monitor which provides a horizontal and

vertical field of view of 37.2 and 21.7 degrees, a 12-inch LCD monitor used as the cluster, an active steering wheel system, and a computer system for simulation and contents provision.
In this study, the driving tendency classification test was determined based on the preliminary test data of eighty examinee and a driving simulator for the driving precision aptitude test was developed as a vocational aptitude test.

Keywords : Driving Precision Aptitude Test, Driving Tendency Classification Test, Driving Simulator, Traffic Safety, Driving Scenario

INTRODUCTION

The components of the road traffic are people, roads and vehicles. Most accidents that we experience everyday are caused by human errors. From 1970 to 1980, traffic accidents were mainly caused by poor vehicle maintenance (ROTA Traffic Accident Analysis Center, 2010). But since the 1980s, the human error has accounted for 90% or more of all accident causes (Rumer, 1985; Treat, 1977). Traffic accidents can, thus, be significantly reduced by preventing the human errors (e.g., driver’s lapse and driving tendency) that cause these mishaps.

The driver’s lapse related to the traffic accidents may be caused by a defective factor in terms of the driver’s aptitude (Cho, 1994). The driver’s aptitude encompasses his visual ability, concentration, reaction, intelligence, driving action, and personality, among others (Klebelsberg, 1982). In 1912, Münsterberg suggested the weak point of the human being as the cause of an accident. Münsterberg likewise proposed a highly reasonable aptitude test by identifying factors such as the mental state and ability that influence the driving activity analysis for the vehicle driver. This was the first driving aptitude test. The driving aptitude test is being conducted worldwide to determine the unqualified drivers and train those who’re qualified as drivers (Lee, 1997).

In Korea, the driving aptitude test has been conducted since 1985 for commercial drivers. The current driving precision aptitude test was developed in 2001, but its efficacy is diminishing because of the disclosure of the testing technique and near obsolescence of the testing equipment utilized for the same and repetitive testing. Accordingly, the Korea Transportation Safety Authority (TSA) has been studying the changing traffic as well as the driving environment. Simultaneously, the TSA has been improving the reliability and validity of the test by introducing an advanced information technology.

The test items, testing devices, and calibration training contents suitable for the environment in Korea were either strengthened or developed using the literature and case surveys to achieve effective testing, increase customer satisfaction, and reduce traffic accidents.

This paper describes the development of the driving simulator, a sensory testing device that uses advanced information technology and the driving tendency classification test, among others.

BACKGROUND OF THE STUDY

In 1984, the government required the commercial vehicle drivers to take the driving precision test in accordance with the commercial vehicle precision test regulation that is implemented by the TSA. The driving precision test examines and assesses the driver's aptitude to detect and correct any defective factors and thus prevent potential traffic accidents due to human factors. The driving precision test has two parts: the initial test and the special test.

The special test is given to drivers who fall under these classifications: (1) those who were employed as commercial vehicle drivers; (2) those who caused any accident which resulted to a serious injury; (3) those who received the accumulated penalty of 81 points or more for the past year based on the administrative standard for licensed driving according to the Enforcement Decree of the Road Traffic Act; and (4) those who should be tested upon the request of a transportation agency to identify whether these drivers can safely drive considering their diseases, excessive labor, or other reasons.

The driving precision aptitude test is conducted among those considered to be vulnerable in terms of safe driving. The current driving precision test, relevant literature, and cases were examined to develop the testing techniques and other elements required to extract and identify the necessary characteristics that help determine vulnerable drivers.

The current testing items and data were analyzed to configure a new testing frame by distinguishing the items with high predictability from those that have none and to rid of any overlapping ones that may exist between the current and the new tests. The intellectual and personality factors together with one's sensory motors are basically included in both the initial and special tests.

For the sensory motor aspect, the basic contents of the testing are similar but may vary in the detailed testing methods. In the special test, the sensory motor test is conducted in a form of simulated driving, wherein the actual driving-related values, including the vehicle speed and lane crossings, are measured. The self-report is used for the driving tendency factor. Table 1 shows the factors and measurement involved in the current special test. Figure 1, on the other hand, shows the current special test device and the sensory motor test screens.

Table 1 Factors and description of the driving precision aptitude test

Factor	Test Title	Check List
Driving Tendency Classification		Weakness (Visual perception, risk expectation, distribution of attention)
Sensory Motor Factor	Sensory Motor (Simulation driving)	Simple response and selective response skills Ability to pay attention to visual and auditory stimuli Ability to estimate the speed of a moving object.
Intellectual Factor	Verbal Faculty	Perceptive fluency
	Reasoning F	Ability to judge, adapt and react to a situation
	Perception Style	Visual judgment
Personality Factor	Anti-Sociality	Violation, irresponsibility, violence inclination
	Neuroticism	Depression, anxiety, anger, impulse inclination
Vision Factor	Kinetic Vision	Kinetic vision and static vision
	Night Vision	Night vision and darkness adaptability

Figure 1 Driving precision aptitude test device and sensory motor factors

In Turkey, professional drivers were surveyed on personality, driving tendency, and accident history to obtain an accident-cause model in terms of personality and behavior (Sümer, 1998). The accident causes related to the driver were summarized in 16 factors to identify characteristics of high-risk commercial vehicle drivers and to select more cautious drivers (Knipling et al., 2004). The bus drivers who caused fewer accidents were more careful than those who caused more accidents and those who obtained calibration training. They drove based on opportunism and tried to comply with even the minor regulations. The drivers who got calibration training tended to shift the responsibility of accidents to their fate or others and tried to show off their driving skill (Park and Lee, 1997). The mortality per 10,000 vehicles is five times higher among commercial vehicles as compared with non-commercial vehicles (Korea National Police Agency, 2008). The accident rate of taxis is actually rising. The driving tendency of taxi drivers were classified into eight types: (1) weak intention to drive safely; (2) poor vehicle maintenance; (3) insufficient tension during driving; (4) slow response to hazardous situations; (5) unskillful guess; (6) competing with other drivers; (7) failure to predict a hazardous situation; and (8) wrong recognition of surroundings (Jang et al., 2008). Safety measures were devised to prevent such accidents.

The Transportation Safety Research and Education Institute, which is run by TSA, provides a driving course on the basic requirements that include the information on regulations, safety driving, and mental training together with vehicular practice and device training. The 3D virtual driving technology is used for the device training which is done by using a driving simulator to provide drivers the experience that may not be obtained from mere vehicular practice and training. The experience from this training is just among the diverse and complex situations presented to commercial drivers who may encounter similar situations while driving on their own. To date, the training institute has 15 driving simulators (Innosimulation, 2008).

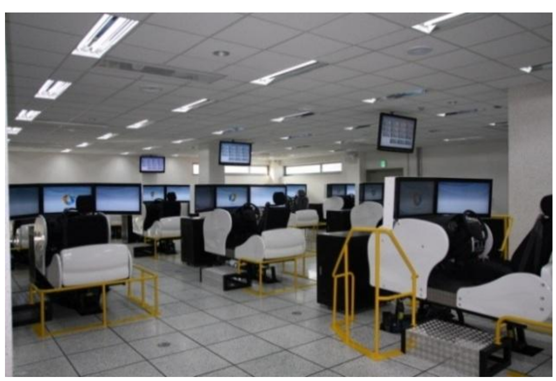
Figure 2 Driving simulators at the Transportation Safety Research & Education Institute

The Vienna Test System (VTS), developed by Schuhfried GmbH in Austria (established in 1947), performs 12.5 million tests annually. This system is used in more than 30 institutes in 65 countries. The time/movement anticipation (ZBA), for instance, is a test that measures the ability to predict the speed and direction in any given space and is very suitable for driving mentality(Schuhfied, 2010). Figure 3 shows the screen shot of ZBA of the special ability tests.

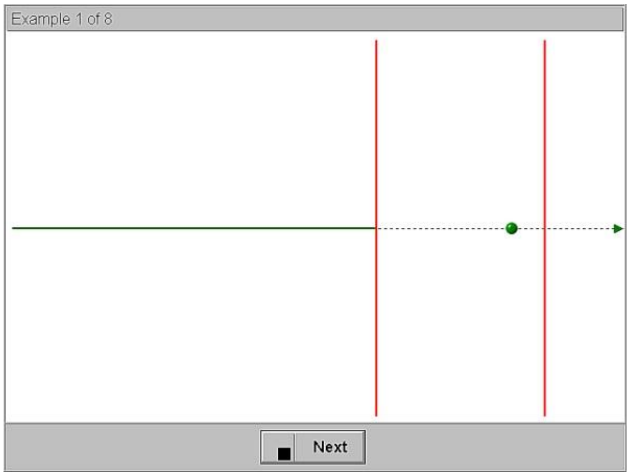

Figure 3 Screenshot of ZBA in VTS

From the examination (i.e., current special test, expert consultation, interview, questionnaire survey, related literature and case studies), the driving precision aptitude test was configured with the personality test, driving tendency classification test, driving hazard perception test, and situation awareness perception test. All items were tested on the driving simulator platform.

This paper describes the driving simulator for the driving precision test and the driving tendency test items. From the interview and questionnaire survey with the expert and examinee groups, the test contents were proposed to measure three major areas: (1) the driving tendency, considering the insufficient practicality of test tools and scenarios; (2) hazards that can be experienced in actual driving situation; and (3) frequent traffic accident cases.

The driving characteristics that frequently cause accidents were classified into three types: (1) signal and sign violation; (2) aggressive and hasty driving; and (3) erroneous driving. Driving scenarios were therefore developed to measure the three driving types in the tendency test.

DEVELOPMENT OF DRIVNG SIMULATOR

The driving simulator is a virtual reality device that simulates in real time the vehicle movement caused by the driver's operations (including steering and acceleration/deceleration) and creates the motion, visual effect, and sound queue as feedback for the driver. Through these incidents, the simulator then provides the driver the feeling of actual driving. The emergency situations and accident cases can be reproduced in a safe and controlled environment; all of which may be impossible to control in actual driving due to certain limitations, including safety, time, and cost to objectively measure the drivers' reactions while training them.

This section describes the hardware and software of the driving simulator. The contents of the driving precision aptitude test, combined with the driving simulator, are described in the next section.

Configuration Diagram

The driving simulator for the driving precision aptitude test consists of the hardware, operating software, and the test contents. The driving precision aptitude test contents are classified into three areas: (1) the driving tendency classification test, (2) the driving hazard perception test, and (3) the situation awareness perception test. Figure 4 shows the overall configuration diagram of the driving simulator for the driving precision aptitude test and testing system by TSA.

Passenger car parts produced in Korea were used for the driving simulator that was developed in this study. The cluster was made similar to the type of general vehicles so that the simulator would have a steering system, seat, and interior design similar to other vehicles. By evaluating the preliminary experiment results and numerous interviews and requests made with experts and examinees, the contents were developed so that they would be similar to actual situations in terms of driving environment, screen configuration, and vehicle dynamic performance characteristics.

Figure 4 Configuration of driving simulator for driving precision aptitude test

Hardware

The driving simulator hardware for the driving precision aptitude test includes the cabin system for vehicle operation (including the driver's seat), the real-time simulation system (including the computer), image creation device, and audio device.

Actual vehicle parts were used for the cabin system to minimize the heterogeneous feeling of the testing equipment. The final cabin design was selected by reflecting the operators' and users' requests of the driving precision aptitude test device at the concept establishment stage. Dimensions were determined as 2,130 mm (Length) x 800 mm (Width) x 1,370 mm (Height),

considering the installation condition of the driving precision aptitude test center.
The cabin system has the steering wheel, multifunction switch, gas and brake pedals, manual transmission and clutch pedal, parking brake, and a seat with safety belts. All of the driver's operations are transferred to the simulation computer via the data acquisition (DAQ) board and CAN interface. An active steering wheel system (ASWS) was used to create the steering force during driving, and an LCD monitor for the cluster was used to check the speed and engine rpm.
The computer specifications were determined so that the stable simulation could be ensured in terms of operation signal detection, graphic rendering, audio output, and real-time vehicle dynamics. The simulation computer performed serial, CAN, and Ethernet (TCP/IP) communications for signal processing.

The image and sound devices were a 32-inch LCD monitor and stereo headphone, respectively. The display device was fixed to the cabin so that the driver could have the widest vision in a stable environment. A room mirror, side mirrors, and a digital tachometer were displayed on the screen to provide driving convenience.

A normally open type push switch was installed at the center fascia for the interface between the driver and the driving simulator. This setup allowed the driver to answer the driving precision aptitude test questions and enter what is required while the test was progressing.

Figure 5 Hardware Configuration

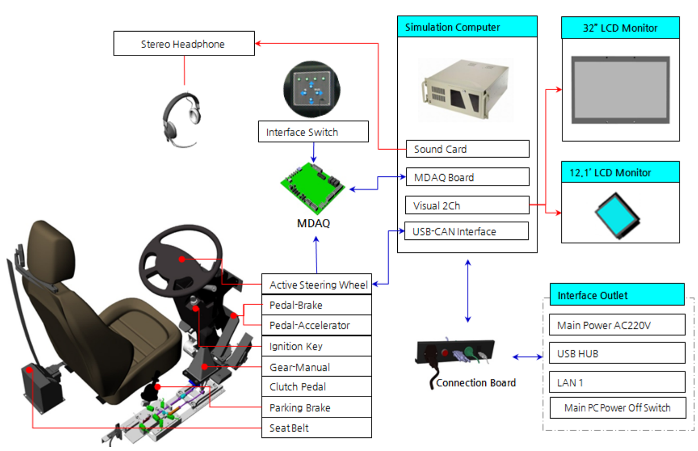

Figure 6 Hardware block diagram

Software

The operation software for the driving simulator must be controlled so that it can provide independent startup, operation, shutdown, and analysis. The operation software consists of a comprehensive driving simulation engine SCANeR© DT, a hardware interface program MDAQ, and a virtual road environment. Figure 7 shows the operation software configuration of the driving simulator.

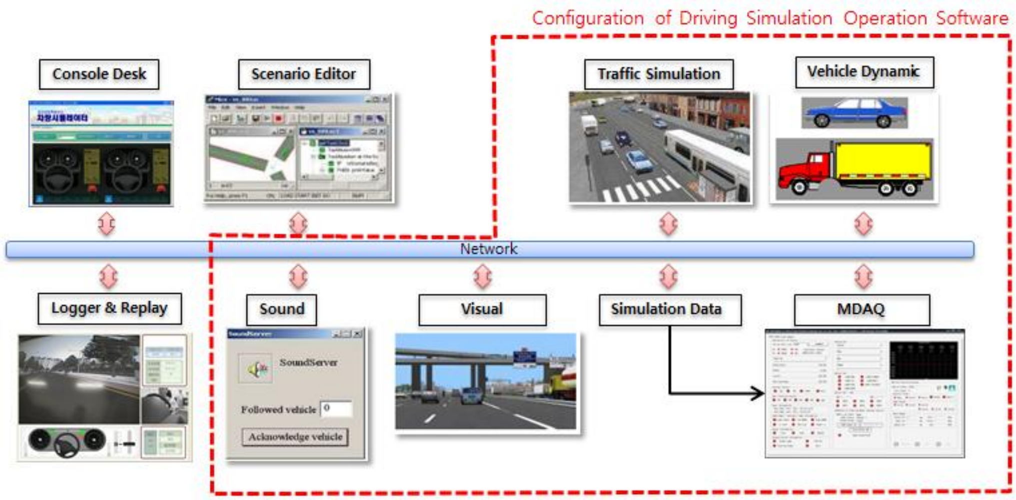

Figure 7 Configuration of driving simulation operation software

SCANeR© DT is an integrated driving simulation program that is based on the well-adjusted traffic simulation, which can be used for human factors engineering, advanced engineering, road traffic research and development, and driver training(OKTAL, 2008). The MDAQ program is a hardware interface program that controls the operation signals of the simulation program, cabin system, and ASWS. The program has a signal processing unit which conducts the analog and digital I/O performance test and signals processing for the steering angle, angular velocity, steering force, gas and brake pedal angles and switches, and a shared memory unit which shares the simulation data.

In addition, it ensures the scalability by providing TCP/IP-based protocol for the control desk to control multiple simulators as well as the independent driving simulator operation. The virtual road environment is the virtual infrastructure of the driving simulator which allows the driver to visually recognize the driving information. This is an important factor for the operation software, along with the simulation engine and hardware interface program. The virtual road environments for urban road (5 km), rural road (6 km), and highway (8 km) were constructed similarly to the actual environments for drivers to configure the test scenarios for desired environment characteristics. The urban road includes intersections, traffic signal systems, traffic safety displays, school zones, residential and commercial areas, crosswalks, and bicycle roads. The rural road includes basic traffic facilities, bridge piers, and curve sections in mountainous areas. The highway includes interchanges, tunnels, speed cameras, and toll gates. Figure 8 shows the constructed virtual road environment.

Figure 8 Virtual road network

Using the driving simulator for the efficient driving precision aptitude test based on the virtual reality, the drivers' usual driving tendencies can be naturally measured while they drive in the virtual road environment. The driving simulator may also be used for the driving hazard perception test, situation awareness perception test, and driving precision aptitude test. Its use may be extended to the personality test.

DEVELOPMENT OF THE DRIVING PRECISION APTITUTE TEST CONTENTS

The configuration of the driving precision aptitude test was configured so that potential, direct, and situation-recognition factors that affect safe driving could be examined. All these factors were integrated in the test results. Figure 9 shows the conceptual diagram for the revised test concept. In this paper, the test items and contents of the driving tendency test, preliminary test and its results, and the final test are described.

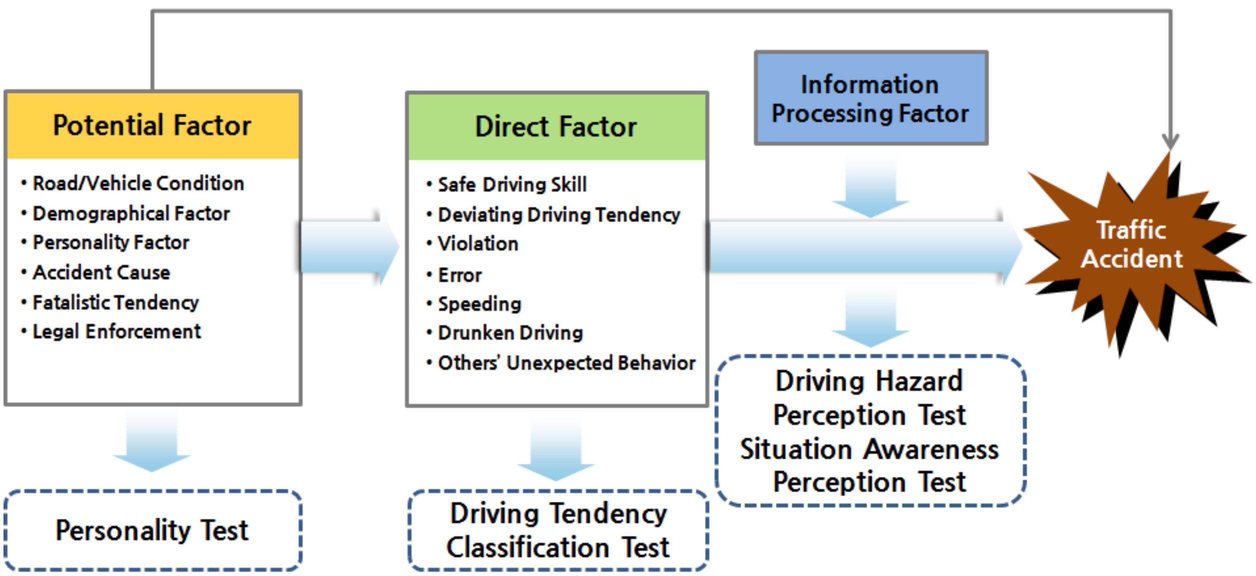

Figure 9 Concept of the driving precision aptitude test

Driving Tendency Classification Test

The driving tendency classification test consists of the simulator test and self-report test, which complement mutually. In the simulator test, three driving tendencies (signal and sign violation, aggressive driving, and lapse types) were assessed in three virtual driving environments (urban roads, rural roads, and highways) and with traffic situation events for measuring eight driving tendencies. The simulator test consists of three driving scenarios for urban and rural roads and highways, and each scenario has eight events to measure the driving tendencies. Repetitive measurements were conducted focusing on the driving tendency factors for three driving tendencies (see Table 2) to improve the discriminatory power. Because the simulator test has a limitation in a way that it cannot directly identify the intention of a behavior, the self-report test was developed with 30 questions to evaluate three types of driving tendencies.

Table 2 Driving behavior patterns and factors

Type	Behavior type
Violation Type	Signal violation: Violation of diverse signals. Sign violation: Violation of instructions, including traffic signs Lane violation: Violation of lanes, including driving and overtaking lanes. Speeding: Speeding above the specified speed.
Aggressive Driving Type	Sudden acceleration/deceleration: Sudden speed change, including start and stop. Sudden change: Sudden change, including the lane shift and turning, without reducing the speed. Prediction driving Unreasonable and unsafe lane change
Lapse Type	Forward-looking negligence: Failure to keep safety distance to the preceding vehicle or expected situation. Implicit estimation: Following the preceding vehicle without checking the frontal situation. Fixed driving: Failure to respond to the traffic environment changes. Ignoring the weather change

<u>Simulator Test</u>

Twenty-nine events were obtained by extracting the cases of frequent accidents based on selected factors, related literatures, accident case analyses, interviews and surveys, and accident cases and black-box analyses from the aptitude test training. The 29 events were based on everyday life situations. They were selected to measure the usual driving tendency in the case of unexpected situations and the behavioral response in situations of actual violation cases for the characteristics of roads and business types.

The possibility of a simulator implementation, discriminatory power, and test items were considered in the development process because one-time behavior should not be identified as habitual behavior, events were configured so that the driving behavior to be measured would be repeated three times or more. The driving purpose and road types vary depending on business types, thus the defective driving tendencies also can be varied. Therefore, the aforementioned three road environments were selected to design the roads; probable events were selected for each road environment and combined for each road scenario with different orders.
To examine how reasonable and predictable the configured scenarios were and to select the events for the test standardization, the preliminary test was conducted among 80 examinees. Figure 10 and Table 3 show a scenario of an urban road driving and test items for the standardized test.

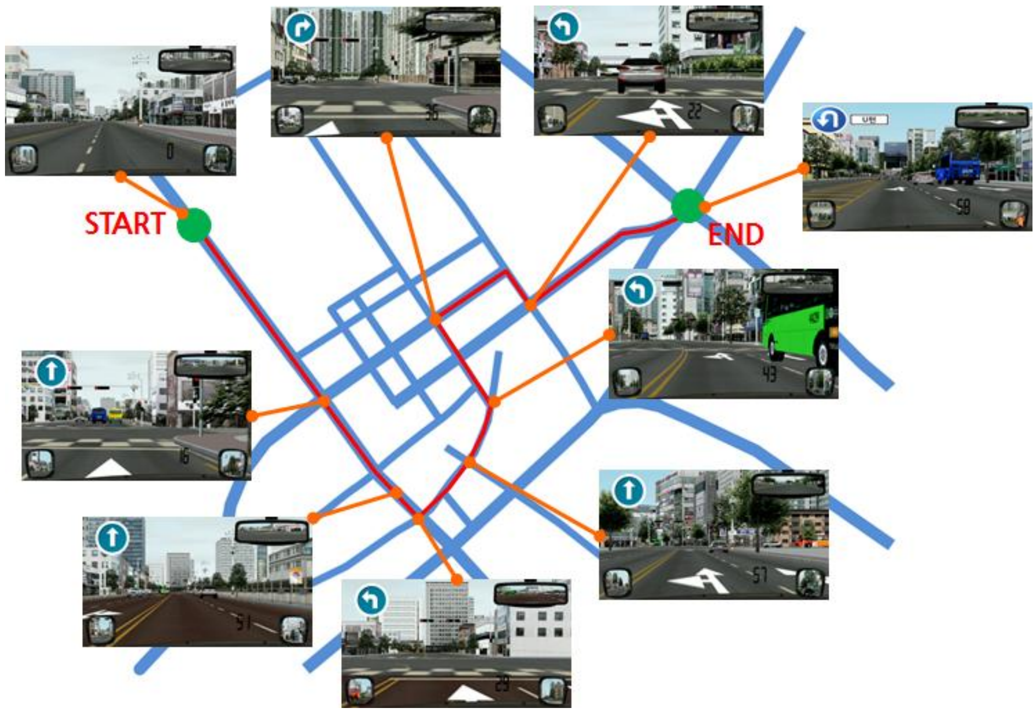

Figure 10 The test driving scenario in the city

Table 3 Events and factors of city test scenario

Scenario	Factors	Measurements
Dilemma Zone (Ⅰ)	Traffic Signal Violation	O/X
	Whether the vehicle stops	O/X
	Stop Line Violation	O/X
	Emergency Stop	Longitudinal Acceleration
	Collision	O/X
Jaywalking	Whether the vehicle stops	O/X
	Stop Line Violation	O/X
	Emergency Stop	Longitudinal Acceleration
	Collision	O/X
Cut-in	Turn Signal	On/Off
	Deceleration	Longitudinal Acceleration
	Lane Change	Yaw rate
	Position of Cut-in	Vehicle ID
	Distance between vehicle	Distance
	Collision	O/X
Turn Right at Pedestrian Crossing	Turn Signal	On/Off
	Whether the vehicle stops	O/X
	Emergency Stop	O/X
	Speed of Pedestrian	speed
	Collision	O/X
Dilemma Zone (Ⅱ)	Traffic Signal Violation	O/X
	Whether the vehicle stops	O/X
	Stop Line Violation	O/X
	Emergency Stop	Longitudinal Acceleration
	Collision	O/X
…	…	…

Self-Report Test

To supplement the simulator test that measures the behavioral response from actual driving by directly identifying the intention of behavior, the basic questions for the self-report test were proposed so that they could be used to identify three driving tendency factors based on the interview, surveys, and accident case surveys. Based on the validity test and preliminary test analysis results for 200 examinees, a total of 30 basic questions with high accident predictability and discriminatory power (sub-factors of which had reliability values [Cronbach α] of 0.70 or higher) were selected. Table 4 shows examples of questions in the self-report.

Table 4 Self-report test

Type	No. of Questions Reliability (Cronbach α)	Question Example
Violation Type	10 Questions ($\alpha = .754$)	I do not stay in the same lane if the situation is considered safe. I always observe the traffic regulations.
Aggressive Driving Type	10 Questions ($\alpha = .756$)	I get rid of stress when I drive fast. I habitually follow the preceding vehicle closely.
Lapse Error Type	10 Questions ($\alpha = .784$)	I often think of other things more than driving when I drive. I sometimes miss the traffic sign and go in the wrong way.

Preliminary and Standardization Test Items

The purpose of the preliminary test is to select the characteristics and aptitude factors for drivers who are vulnerable to accident risk and test techniques that efficiently identify the factors. The preliminary test also determines the final driving precision aptitude test which includes tests for personality, driving tendency classification, driving hazard perception, and situation awareness perception.

While using all test contents for the driving precision aptitude test, the preliminary test was conducted for the examinees to identify the characteristics of the examinee group and determine the final test contents considering the validity, predictability, and discriminatory power of the designed questions and scenarios (see Figure 11).

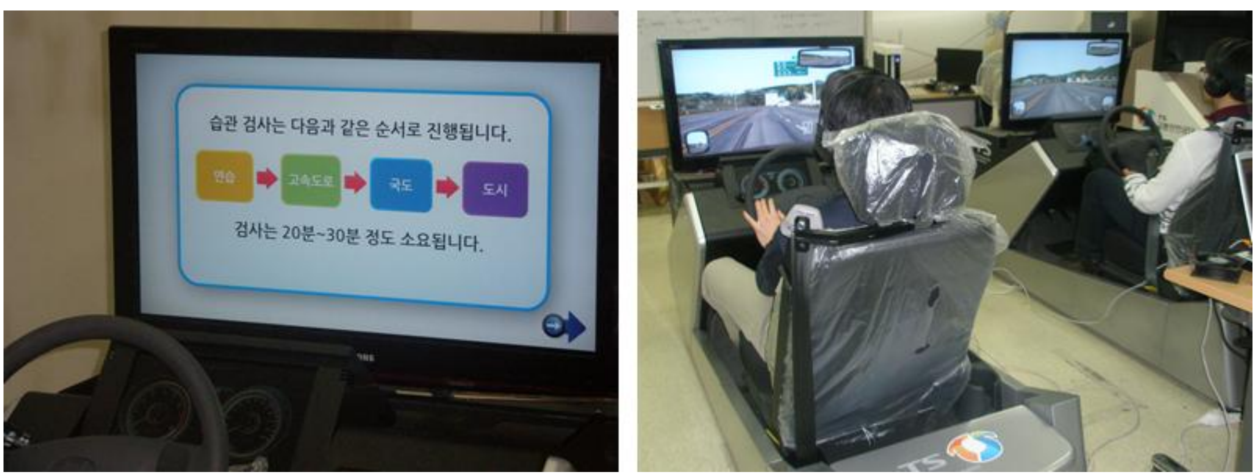

Figure 11 Preliminary experiment

The preliminary test was conducted in the test center of TSA and was divided into personality and simulator performance tests. The personality test was conducted among 207 examinees in three test centers. Among the performance tests, the driving tendency test was conducted among 80 examinees, and the driving hazard perception and situation awareness perception tests were conducted among 69 examinees. The collected preliminary test data were analyzed via the questionnaire analysis, response distribution analysis, and verification of reliability and discriminatory power. While using the regression analysis of preliminary test results and the accident history and penalty scores of the examinees who participated in the test, the predictability analysis was conducted to ensure the validity for each measurement indicator.

Preliminary Tendency Test Results

The response distribution analysis and predictability analysis were conducted for the preliminary tendency test results. The response distribution analysis is conducted to identify the validity of the measurements. The event with an abnormal measurement can be properly selected. The response distribution analysis checks if the response is induced as it is originally designed. If an event that was designed to increase the speed does not result in the speed increase response, the design of the event can be considered wrong. But if it results in the speed increase response, it can be considered appropriate.

Even though the personal characteristics are considered, no increase in every event means the problem in the event design. In the case of a pedestrian jaywalking in the urban street, it is expected that most drivers will suddenly stop or decelerate as soon as they encounter the pedestrian. Figure 12 shows that a small number of examinees gradually decelerated, whereas most drivers suddenly stopped or decelerated. Therefore, this event was selected as the final test event.

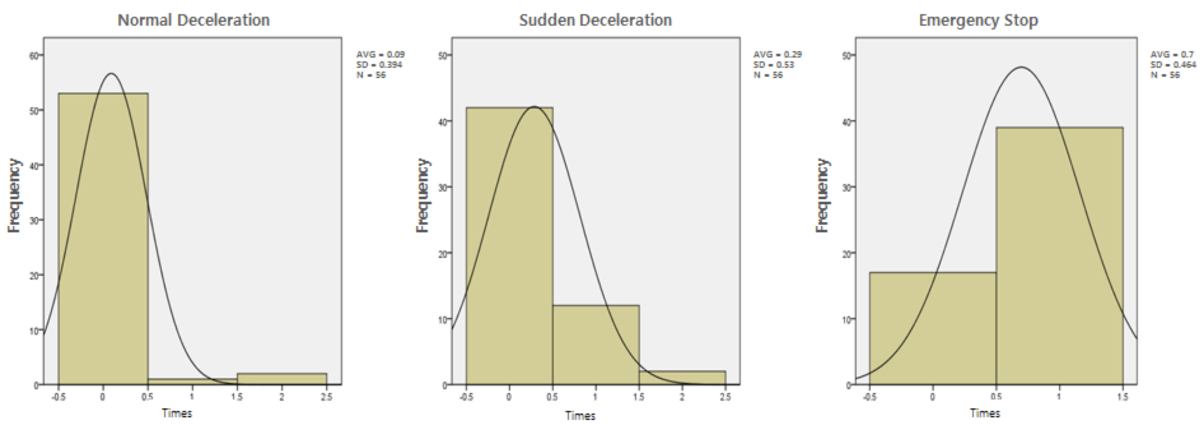

Figure 12 Response distribution of jaywalking event

For the event of surrounding vehicles speeding on the rural road, it is expected that the examinees will maintain or increase their speed according to the speed of surrounding vehicles. In the response distribution results from the preliminary test, however, they showed abnormal responses, including sudden deceleration or stop (see Figure 13). Therefore, this event was excluded from the final test events.

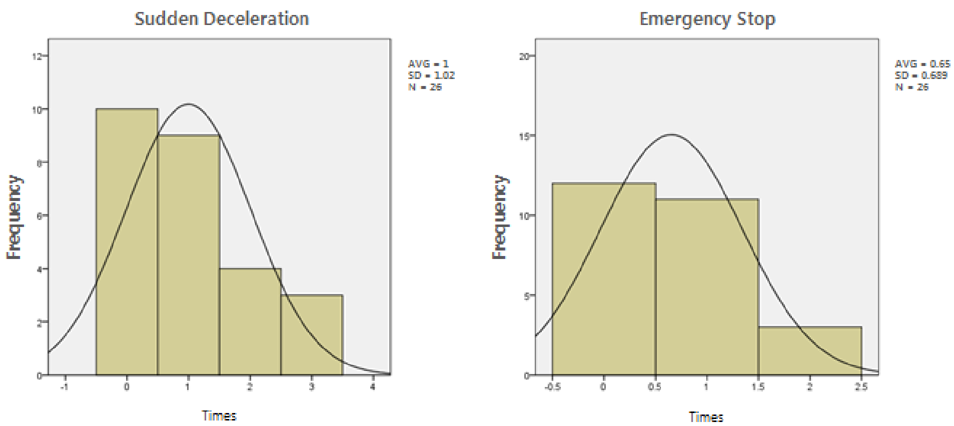

Figure 13 Response distribution of surrounding speeding vehicles

The predictability analysis was conducted for the events in the driving scenario to ensure the reliable and accurate driving tendency results. The purpose of the tendency test is to measure the driving tendencies that are related to the traffic accidents. Therefore, the predictability of each measurement indicator was analyzed using the regression analysis of the indicators that correspond to the risky driving tendencies and the number of accidents in the self-report that shows the actual accident tendency and the number of accidents by examinees, as provided by TSA and the accident penalty scores.

The events (the predictability of which was insignificant for the accident tendency indicators) were also excluded from the final test. In the dilemma zone experience event, the simple regression analysis was conducted with the signal violation, stop line violation, speeding, and sudden deceleration, among others, as independent variables. With the self-report, the number of accidents and accident penalty score became the dependent variables. As shown in Table 5, the measurement indicators were significant to the dependent variables, and this event was selected as the final test event.

Table 5 Predictive analysis of dilemma zone

	Signal violation		Stop line violation		Speeding		Sudden deceleration	
	β	p	β	p	β	p	β	p
Self-report	.677	.000	.181	.305	.385	.027	-.195	.268
No. of accidents	.212	.343	.433	.039	.061	.786	-.358	.102
Accident penalty	.554	.008	.421	.051	.318	.149	-.457	.033

Meanwhile, the sudden stop, speeding, and sudden acceleration and deceleration, which were the measurement indicators in the event of the preceding vehicle's sudden stop, were insignificant to the dependent variables. Accordingly, this was not selected as the final test event (see Table 6).

Table 6 Predictive analysis of the preceding vehicle's emergency stop

	Signal violation		Stop line violation		Speeding		Sudden deceleration	
	β	p	β	p	β	p	β	p
Self-report	.111	.389	.109	.391	.700	-.098	.595	-.135
No. of accidents	.954	.020	.394	.286	.321	-.330	.126	-.490
Accident penalty	.396	-.011	.218	.341	.675	-.423	.286	-.578

Final Configuration of the Driving Precision Aptitude Test

The tests for the driving precision aptitude test were finally determined to be consisted of the driving tendency test, driving hazard perception test, situation awareness perception test, and personality test—all of which are simulator tests. The tendency test is conducted in the simulator, with three driving scenarios (eight events each for urban road, rural road, and highway). The self-report tendency test with 30 questions is used to assess three factors. The driving hazard perception test provides a pool of 31 video clips, 10 of which are presented to the examinee, 5 each for Type A and Type B in the quasi-wireless type. The situation awareness perception test provides a pool of 48 photographic stimuli, 26 of which are presented to the examinee in the quasi-wireless type. The personality test of 135 questions is used to assess six factors. It takes an hour and 40 minutes to complete the test.

CONCLUSIONS AND RECOMMENDATIONS

It is expected that the driving simulator developed in this study will contribute to the improvement of national traffic safety by ensuring the higher quality of precision test and training via experiential training. The driving tendency classification test especially presented a new direction of the driving aptitude test in the examinees' driving tendencies and was naturally measured during their driving along a virtual road environment.

This test is also advantageous in ways of converting the test type to an experiential precision test type with a new paradigm which solves the energy and gas emission issues. This considers the current global warming and energy crisis in view of economic effects and also achieves the employment creation and environmental protection.

Although the driving simulator test has an advanced test method and realistic configuration, there is a problem that the simulator sickness of the examinee must be reduced to a minimum level. Many attempts and studies are underway for the same purpose.

For practical application of the driving precision aptitude test, the standardization test is underway for a thousand examinees. Based on the results, the standards for test items will be defined and the contents for overall evaluation and calibration training will be developed.

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