A Study on Safety Verification Methods and Procedures for Self-Driving Demonstration

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Abstract— This paper established three criteria for safety verification for autonomous driving demonstration projects. We diagnosed safety verification for three autonomous driving demonstration projects according to the criteria. We reviewed the inspection of the safety design of autonomous vehicles, the establishment of safety measures suitable for the demonstration environment, and the evaluation of the safety of the designed ADS to ensure safety.

Keywords—safety; autonomous driving demonstration; safety verification; self-driving car; diagnosis

I. INTRODUCTION

For self-driving cars' successful development and commercialization, safety must be guaranteed above all else. To this end, standards and measures for safety must be established from the demonstration stage, and sufficient tests and verification must be conducted. Standards and procedures are needed to verify the safety of self-driving demonstration projects in progress to provide various mobility services.

II. ANALYSIS OF DOMESTIC AND FOREIGN AUTONOMOUS VEHICLE SAFETY-RELATED POLICIES

The United States, Singapore, and many more countries present safety regulations for the safety of self-driving cars and recommend those self-driving car companies must follow them. The National Highway Traffic Safety Administration (NHTSA) under the United States Department of Transportation (USDOT) announced guidelines for self-driving cars. In addition, Europe has unveiled two roadmaps (EPoSS, ERTRAC), including the Vienna Convention [1] [2]. In this way, many countries, including Europe, Japan, and Singapore, are establishing policies related to autonomous vehicle safety.

A. Domestic Self-Driving Temporary Operation Permit System

Since 2016, South Korea has also allowed self-driving cars to test run on all roads, except the protection section for the transportation vulnerable, regardless of the level of self-driving, provided that the minimum requirements for safe operation are satisfied. The period of permission for temporary operation of self-driving cars in Korea is up to five years, and there are three types : type A, type B and type C.

Type A is a self-driving vehicle with a steering wheel, accelerator, brake pedal, and a test driver ride on it. Type B is an autonomous vehicle without a steering wheel, accelerator, or brake pedal, and a test driver rides on it. Type C is an autonomous vehicle without a test driver. It is an autonomous vehicle managed remotely from the outside. Each type must meet different requirements for self-driving cars.

B. Autonomoous Driving Safety Standards by Country

The J3016 autonomous driving system classification by the American Society of Automotive Engineers (SAE) is becoming an international standard [3]. This document covers various definitions and concepts related to autonomous driving, including Dynamic Driving Test (DDT), Automated Driving System (ADS), Operational Design Domain (ODD), Object and Event Detection and Response (OEDR), Minimal Risk Condition (MRC) and many more.

In 2017, the US NHTSA announced Automated Driving System 2.0, A Vision of Safety (ADS 2.0), which complements the guidelines published in 2016 [4]. AV 2.0 consists of safety elements (Chapter 1) and state technical guidelines (Chapter 2) for developing and testing autonomous driving systems. In the 12 items of the autonomous driving system safety guideline, voluntary safety self-evaluation is required to prevent road users from being exposed to danger when testing.

TR68 was established in March 2020 by the Automotive Technical Committee of Singapore's Manufacturing Standards Committee [5]. It provides the basis for ensuring the safe operation of self-driving cars and the interoperability of cybersecurity and data. TR68 consists of four parts: Basic behavior in Part 1, Safety in Part 2, Cybersecurity principles and assessment framework in Part 3, and Vehicular data types and formats in Part 4.

C. Safety Guidelines of Self-Driving Vehicles Around the World

Several countries, including the United States, Canada, Japan, and Europe, are establishing guidelines for safe autonomous driving. The terms defined in the guidelines for each country were reviewed, and the items commonly provided were derived, compared, and analyzed as shown in Table Ⅰ.

TABLE I. COMPARATIVE TABLE OF SAFETY GUIDELINES FOR SELF-DRIVING CARS IN DIFFERENT COUNTRIES

Items	USA	Canada	Japan	EC	Australia	China
System Safety	O		O	O		
ODD	O	O	O	O	O	O
OEDR	O	O		O	O	
Fallback-MRC	O	O		O	O	
Safety Verification	O	O	O	O	O	O
HMI	O	O	O	O	O	O
Cyber Security	O	O	O	O	O	
Crash Resistance	O					
Post-crash Behavior						
Data Recording	O		O	O	O	O
User/Driver Training	O	O	O	O	O	O
Related laws	Federal, State and Local laws					
Automation Level and Purpose of Use		O				
Compliance with international standards and safety regulations		O	O	O		O
System Updates and Aftermarket Repairs/Modifications	10	O	10		O	
User Personal Information		O			O	
Accident Data Sharing	10	Sharing with government agencies and law enforcement	10		O	
Control Center and Vehicle condition monitoring			Unmanned vehicle emergency notification	Driving Center In-vehicle monitoring		

III. ESTABLISHMENT OF SAFETY STANDARDS FOR SELF-DRIVING DEMONSTRATION AND IMPLEMENTATION OF DIAGNOSIS

As a criterion for determining the safety of self-driving demonstrations, three review criteria were established: the safety of self-driving vehicles, safety measures during demonstration implementation, and whether the verification goal was achieved. Under the three standards presented, safety was reviewed in three stages: inspection of the safety design of autonomous vehicles, establishment of safety measures suitable for the demonstration environment, and evaluation of the safety of the designed demonstration ADS.

A total of three self-driving demonstration projects were evaluated: demonstration of self-driving service in city-specific exclusive space, demonstration of self-driving service in city parks with citizen participation, and foundation establishment for collecting and sharing autonomous driving data.

A. Establishment of Safety Standards for Self-Driving Cars and Results of Diagnosis

We utilized the items presented in the ADS Safety Guidelines (NHTASA, USA) [6], the Level 4 Self-Driving Vehicle Manufacturing and Safety Guidelines (Korea Ministry of Land, Infrastructure and Transport), and the Self-Driving Demonstration Safety Guidelines (Sejong City, Korea). Realistic review criteria were prepared to fit the self-driving demonstration project, and safety verification items were derived to suit the business conditions.

Based on the derived safety verification items, what, how, and in what way the operators performed were reviewed, and to what extent and to what level the safety of self-driving cars and self-driving services were demonstrated was analyzed. The table below shows the analysis items for the derived safety verification. Table Ⅱ shows analysis items for safety verification of autonomous vehicles.

B. Establishment of Safety Measures Standards for Each Autonomous Driving Demonstration Project and Results of Diagnosis

Depending on the self-driving service demonstration project, the exceptional cases applied in the designated demonstration section are different, the purpose and goal of the demonstration are different, and the vehicle and demonstration section are different, so specialized safety management is required for each project.

Self-driving vehicles driving at high speeds on public roads and BRT roads in the city and autonomous vehicles driving at low speeds in residential complexes are not simply different in driving speed. Physical conditions such as vehicle size and passengers who can board are primary, and physical, managerial, technical, and economic factors to be considered, such as boarding targets, service purpose, and road driving environment, are very diverse.

TABLE II. ITEMS FOR SAFETTY VERIFICATION OF AUTONOMOUS DRIVING DEMONSTRATION

No.	Safety Verification Items	Test and Verification Method
1	Demonstration Operating Condition	· Environmental analysis of the demonstration roads in Sejong City - When operating a specific service on a test road in Sejong City, precise environmental analysis is required for the specific road due to limited environmental conditions (road type, area, speed, range, weather, and many more conditions)
2	Measures to respond to Objects and Events	· Establishment of preemptive action plans and countermeasures against various possible events or unpredictable threats - In addition to environment analysis of a specific road, it is necessary to respond/countermeasure/response/action plan to events or unpredictable threats caused by objects (cars, bicycles, people, animals, obstacles) that may occur while driving on the road.
3	Emergency Response Plan	· Response plan/plan in case of emergency (system failure, ODD departure) (Fallback transition) - Establishment of countermeasures/plans for emergencies such as H/W or S/W functional defects or functional failures/errors of the autonomous driving system, and countermeasures/plans to convert ADS/driver problems to minimum risk status
4	Verification Methods and Procedures	· Methods and procedures for testing and verifying autonomous driving system functions of demonstration vehicles - It is necessary to develop an ADS safety verification methodology and a test evaluation procedure to verify whether the self-driving vehicle has been safely designed and implemented through simulation, test driving, and verification of actual road driving.
5	Human-Machine Interface	· Autonomous Driving System Function (HMI) Implementation Status · Provide essential information to the driver or passengers - System operation status, current autonomous driving mode, system function defect or malfunction, control transfer
6	Crash Scenario Response Plan and Occupant Protection System/Measures	· Collision scenario response plan · Occupant Protection System/Measures · Safety measures according to operational requirements of demonstration service
7	System Behavior After a Crash	· Implementation status of technical functions for emergency measures (Fail-safe, Fail-operational, redundancy) · Plans/measures to minimize exposure to additional risk factors after collision
8	Data Recording	· Verification goal from the perspective of safety verification · Test evaluation results on closed roads/test roads · Results of measures taken against dangerous situations and system failures that occurred during a demonstration

It is necessary to derive collision scenarios that can occur in various situations in the demonstration area (crosswalks, child protection areas, intersections, roundabouts, stop areas and many more) and establish safety measures to cope with dangerous situations while complying with traffic laws and regulations.

Therefore, by dividing each demonstration project into pre-demonstration measures, during demonstration operation, and post-test measures, what kind of safety measures the business operator established for the performance of the verification service, and what procedures and methods were used to implement the safety measures were reviewed.

No.	Safety Verification Items	Test and Verification Method
1	Precaution	▪ Safety measures according to operational requirements (including ODD and crash scenarios) ▪ Fallback-Minimal Risk Condition) ▪ Precautionary measures such as training for managers and operators ▪ Exceptional additional conditions for substantiation (Acquisition of temporary driving permit, liability insurance, establishment of safety inspection manual, reflection of personal information de-identification system, notification to users)
2	Measures taken during demonstration operation	▪ Whether a safety officer is on board to prevent safety (accidents) in the verification process ▪ Action Manual in case of emergency ▪ Safety measures for items related to vehicle occupant safety protection
3	Post-action response	▪ Safety measures for collision accidents or post-accident measures

Fig. 1. Diagnosis items for safety measures of autonomous driving demonstration service

C. *Establishment of Target Achievement Standards for Each Autonomous Driving Demonstration Project and Results of Diagnosis*

Due to regulations, it was previously impossible for autonomous vehicles to drive on roads with other vehicles or in parks. However, Sejong City has been designated as a regulation-free special zone and is demonstrating the self-driving shuttle service in which passengers board through step-by-step demonstrations in some sections of the BRT and some areas of Central Park.

We confirmed the final goal for each demonstration project's specific autonomous driving service demonstration, reviewed how the demonstration goal was achieved, and whether the contents for the service demonstration were faithfully performed. In addition, it was analyzed whether operators implemented measures to ensure safety, such as data collection for safety verification.

IV. CONCLUSIONS

In this paper, three criteria were established as safety criteria for self-driving demonstration: the safety of self-driving vehicles, safety measures during demonstration implementation, and whether the demonstration goal was achieved.

According to the established criteria, safety verification for three autonomous driving demonstration projects was diagnosed. As a result of a comparative analysis of the safety verification data of operators for each demonstration project, it was generally found that a countermeasure plan to secure safety was established and followed. To accurately diagnose the safety of vehicle functions, it seems necessary to identify procedures and methods for identifying whether the ODD and OEDR of autonomous vehicles designed by operators are designed appropriately for the demonstration environment.

Since the road environment and driving conditions are different for each demonstration service, and the safety standards for proving the safety of each service provider are ambiguous, it seems that safety can be sufficiently demonstrated only when sufficient additional demonstration data is secured.

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REFERENCES

[1] UNECE FRAV, "Functional Performance Requirements for Auttomated Driving Systems and ADS-Equipped Vehicles," FRAV Status Report, UNECE, GRVA-05-40, Feb. 2020.

[2] UNECE FRAV, "Common Functional Performance Requirements for Automated Driving Systems and ADS-Equipped Vehicles," UNECE, WP29-180-10, Mar. 2020.

[3] SAE International, "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehciels," SAE International, USA, J3016, Jun. 2018.

[4] NHTSA, "Automated Driving System 2.0, A Vision of Safety," USDOT, USA, 2018.

[5] Singapore Standards Council, "Technical Reference for Autonomous Vehicle," Enterprise Singapore, Singapore, ICS 03.100.70; 43.020, 2019.

[6] Staplin, L., Mastromatto, T., Lococo, K. H., Kenneth W. Gish, K. W., & Brooks, J. O., "A Framework for Automated Driving System Testable cases and Scenarios," NHTSA, Washington, DC, USA, Rep. DOT HS 812 623, Sep. 2018.

[7] Moonsik Kim, "European autonomous vehicle technology roadmap (EPoSS, ERTRAC) analysis, " KEIT PD Issue Report 2015, VOL. 15-12, 2015. (*in korean*).

[8] Hyunsuk Kim and 6 others, "A Study on Human Factors Guidelines for Level 3 Automated Vehicles," ETRI Electronics and Telecommunications Trends, Vol. 35 No. 6, 2020. (*in korean*).