Model-Based Methodology for Social Acceptance Assessment of Autonomous Driving Vehicle

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ABSTRACT: Model-based assessment methodology for social acceptance of Autonomous Driving Vehicle considering advantages and disadvantages is proposed. Basic framework of assessment methodology is introduced and the representative example of the assessment is discussed.

KEY WORDS: electronics and control, Autonomous Driving System, Assesment / Intelligent driving assist system [E1]

1. Introduction

The huge activities on the research and development of Autonomous driving systems are expected as the evolution in the car transportation societies. In order to achieve global efficiency, not only the R & D process, but also international harmonizing moderations, such as standardization, regulation and social acceptance assessment, are very important.

A large number of studies on social acceptance assessment for Autonomous driving systems are discussed (1)-(3). The studies are related to various fields of researches, such as the investigation on human driver’s responses at the transit process from autonomous to manual driving, the survey on field operational tests, the survey on subjective opinion to adoption of autonomous driving vehicle, the analysis on risk prediction for autonomous driving and so on. These studies evaluate the social acceptance for Autonomous driving vehicles (ADV) only for the individual subjects, that are restricted technology areas, individual driving conditions, restricted road environments and/or individual autonomous level. They does not discuss total social acceptance assessment, if autonomous driving vehicles are adopted to daily car transportation. A major cause of lack of total social acceptance assessment is considered that the methodologies for the assessment is not concreted. This paper discusses the model-based methodologies for total social acceptance assessment of Autonomous driving vehicles.

2. Requirements and Model-based Methodology in Social Acceptance Assessment for ADV

In discussing social acceptance assessment, following items should be considered in each autonomous level of the systems;
- Advantages of ADV
- Disadvantages of ADV
- Technological problems
- Social problems

In the design process of autonomous driving systems, the advantages should be settled as great as possible. Also in the design process, the disadvantages are settled as small as possible.

After designing process, technological problems and social problems are extracted and are discussed to create the optimum solution. These discussing process is largely effected by the design of the system, based on the autonomous level, the operational design domain (ODD) and driving condition. The final assessment of each design of autonomous driving system should be concluded, after the qualitative and quantitative evaluation of the advantages, the disadvantages, the technological problems, the social problems and the final system design as an optimum solution.

Throughout these considering, model-based assessment methodology of social acceptance for autonomous driving vehicles are designed and proposed as shown in fig.1. “Model-based” means that the proposed methodology has analytical structures for assessment process, as shown in fig.1.
Step 1-3: Analyze and summarize the results of each evaluation
Step 2: Disadvantage analysis of ADV
Step 2-1: Clarify major items of disadvantages for ADV
Step 2-2: Break down the major items to detailed items
Step 2-3: Analyze and summarize the results of each evaluation
Step 3: Total assessment for social acceptance of ADV
Step 3-1: Connect the results of assessments for advantages and disadvantages
Step 3-2: Discuss availabilities of technology to solve the problems
Step 3-3: Discuss development of laws
Step 3-4: Estimate system costs and social costs including R&D
Step 3-5: Select the target of ADS
Step 3-6: Share the target between researchers and engineers globally

In each step, the automated levels defined by SAE, as shown in fig.2, are referred. In this paper, Step 1 and Step 2 are discussed in detail as one representative example of social acceptance assessment for ADV.

### Fig. 2 SAE International’s new standard J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems

#### 3. Advantage Analysis of AVD (step1)

#### 3.1. Major Items for ADV Advantages (Step1-1)

Major items for ADV advantages are clarified as shown in fig.3. First of all, ADV is considered to contribute to improving traffic safety. Secondly, improvements in driver’s convenience and comfort easily occur to everyone. Traffic efficiency and fuel consumption efficiency are well discussed in ADV deployment process. Finally, new businesses are very well expected as social innovation with realization of ADV transportation.

#### Advantages of autonomous driving
- Improve Traffic Safety
- Improve Driver’s Convenience & Comfort
- Improve Traffic and Fuel Efficiency
- Create New Business

#### Fig. 3 Major items of advantages for ADV

#### 3.2. Breakdown of Major Advantage Items (Step1-2)

Procedure of breakdown process is to apply WBS (Work Breakdown Structure) method which is deliverable-oriented breakdown of a project into smaller components in project management and systems engineering.

3.2.1 Break down of traffic safety improvement

The results are shown in fig.4. ADV is considered as safer vehicle, because it avoids human drivers mistakes, but it depends on the reliability and accuracy of the system. As a driver’s workload of operation could be decrease, so the driver is less tired. While autonomous driving, driver could observe more wide area. Cognitive system in ADV could detect obstacle more reliably than a human driver.

#### Fig. 4 Breakdown of Traffic Safety

3.2.2 Breakdown of driver’s convenience and comfort improvement

Fig.5 shows the results of breakdown of driver’s convenience and comfort. A driver could use driving time freely in ADV and rest even during drive, in level 4 or level 5 of automation. Disabilities or older people who could not drive usual vehicle could drive ADV, so ADV is considered to become a good transportation tool for aged society. Also, ADV could be good transportation in unpopulated area.

#### Fig. 5 Breakdown of convenience and comfort

### Improving Driver’s Convenience & Comfort
- Give drivers time to do freely during driving
- Give drivers rest during driving
- Give disabilities or older people free driving
- Give aged society transport mean
- Give unpopulated area transport mean
- Park easily
- Drive overnight in journey
- Pick up yourself or families automatically

Unskilled drivers might not be good at parking operation, but ADV could make them easier to park. Future dream of overnight journey, giving full driving authority to ADV, could
come true in level 5. Human being could obtain new way of travel, that be picked up at appointed place by ADV in level 5.

3.2.3 Breakdown of traffic and fuel efficiency

Fig. 6 shows the breakdown results of traffic and fuel efficiency. Traffic congestion might be decreased by the micro and macro managements of traffic flow, that schedules optimum vehicle speed control and that selects optimum path to destination. Each driver could drive ADV at faster speed, and the number of traffic lanes could be expanded by precise lateral control.

Fig. 6 Breakdown of traffic and fuel efficiency improvement

3.2.4 Breakdown of new business

Fig. 7 shows the results of breakdown of new business. Taxi without a human driver could be realized by level 5. Various way of car sharing and logistics could be concreted. New local transportation, like last one mile autonomous driving, could be possible. If regal problems are solved, a driver could drink beer and wine freely. Also, ADV could be transportation for young children.

Fig. 7 Breakdown results of new business creation

3.3 Analysis and Summarization of Each Evaluation Results

3.3.1 Analysis of Traffic Safety for ADV

The most important item in traffic safety area is prevention of traffic accidents. So the possibility of decreasing the number of traffic accidents could be major index of traffic safety evaluation area by ADV. Considering both of automated levels and ODD, the assessment results are shown in Fig. 8.

In each evaluation for the combination of the individual level and the individual ODD, quantitative and qualitative investigation of following items are need;
- Select system concept
- Select use case of advantage
- Extract technical and social problems
- Select the optimum solution
- Decide direction of technology deployment

Fig. 8 Assessment results for advantages of ADV

Each investigation could be conducted, on demand from each situation, by various way as following methodologies;
- Survey of Traffic and Accident Statistics
- Computer Simulation
- Driving Simulator Tests
- Near Accident Data from Drive Recorder
- Proving Ground Tests
- Field Operational Tests

For one example of accident statistics survey, safety assessment in the ODD of expressway is low point, because the traffic accidents rates in expressway is very low, as shown in fig.9.

Fig. 9 Traffic accidents statistics in Japan

3.3.2 Analysis of Driver’s Convenience and Comfort Improvement

Driver’s convenience and comfort by ADV is different, depending on the level of automation. In level 2, drivers have stress to keep watching traffic environments, while he is free from driving operations. So, convenience and comfort improvement is considered as none or little. In level 3, drivers should keep waking to get ready for driving again. So, even in the level 3, convenience and comfort improvement is considered as little. In level 4 and 5,
drivers could achieve free from driving operation and safety observation. In these levels, drivers’ convenience and comfort could improve much.

3.3.3 Integrating Assessment for ADV advantages

Fig.10 shows representative example of assessment for ADV advantages.

| Example of assessment for advantages (draft) |
|---|---|---|---|---|
| Level | CDD | Safety | Convenience | Efficiency/ New business |
| 3 | Expressway | Little | Little? | none |
| 3 | All roads | ? | little? | none |
| 4 | Expressway | little | medium | little |
| 4 | All roads | Medium-large | large | medium |
| 5 | All roads | large | large | large |

Fig.10 Representative example of assessment for ADV advantages

4. Disadvantages Analysis (Step2)

4.1. Major Items for ADV Disadvantages (Step2-1)

Fig.11 shows the results of clarification of major items in disadvantage analysis.

| Disadvantages of autonomous driving |
| --- |
| Create traffic accidents |
| Be used as application of crime |
| Disturb mixed traffic flow |
| Decrease driver’s ability of driving |
| Create new problems to judge responsibility in traffic accidents |
| Increase unemployment of professional drivers |
| Cost |

Fig.11 Major Items of Disadvantages for ADV

We should consider the additional traffic accidents caused by ADV. ADV could be very good tools to a criminal, could disturb mixed traffic flow, could decrease operational abilities of drivers, could create complex responsibilities of driving, could discharge professional drivers and needs enormous cost.

4.2. Breakdown of Major Disadvantage Items (Step2-2)

4.2.1 Breakdown of Traffic Accident Creation

As shown in fig.12, ADV could result the lack of driving operation by overconfident drivers. While drivers drive ADV, they could have the possibilities of sleep because of no operation. Safety functional guarantee of ADV systems is very difficult subjects. The system could not detect the situation of exceeding functional limit of system. Hackers could easily attack ADV systems. And these could cause traffic accidents.

Create Traffic Accidents
- Caused by driver’s overconfidence
- Caused by driver’s sleep
- Caused by system’s failures
- Caused by exceeding functional limit of system
- Caused by cyber attack

Fig.12 Breakdown of Traffic Accidents Creation

4.2.2 Breakdown of Application of Crime

Fig.13 shows the results of breakdown of crime application. ADV could be very convenient for terrorists to settle bomb, and they could not need to rely on dead bombing. Kidnappers could use ADV very conveniently to abduct someone and also criminals could be helped to get away by ADV.

Be used as application of crime
- Settle bomb by terrorist
- Used by kidnappers
- Used as get away mean by criminal

Fig.13 Breakdown Results of Crime Application

4.2.3 Breakdown of Disturbing Mixed Traffic Flow

ADV could not communicate directly to the drivers of other vehicles, and be usually design each function as considering safety margin. So ADV has the tendency of hesitating the progress of driving in mixed traffic flow, as shown in fig.14. These hesitation of ADV could disturb the traffic flow and make congestion.

Disturb mixed traffic flow
- Hesitate at stop sign intersection
- Hesitate at lane change
- Hesitate to turn as crossing oncoming car
- Hesitate to pass each other at narrow width point of road

Fig.14 Breakdown Results of Disturbing Mixed Traffic Flow

4.2.4 Breakdown of Decreasing Driver’s Ability

Fig.15 shows the results of breakdown of decreasing driver’s ability. ADV deprives human drives of driving operational time largely. Overconfidence of drivers to ADV makes drivers operate under easy tasks. So, ADV deprives human drivers’ care, cognitive performance and judging performance. Also, human drivers’ operating skill of handling and braking control could be decreased.
4.2.5 Breakdown of Responsibility Problems
ADV is operated not only by onboard systems and by drivers, but also by road infrastructure and by communication systems. So the responsibility problem could spread to the relationship between the four elements, as shown in fig.16.

Create new problems to judge responsibility in traffic accidents
- Responsibility between driver and system (manufacturer)
- Responsibility between car and road infrastructure
- Responsibility between car manufacture and communication managing company

Fig.16 Breakdown Results of Responsibility Problems

4.2.6 Breakdown of Unemployment Problems
ADV in level 5 could be replaced by human professional drivers, as shown in fig.17.

Increase unemployment of professional driver
- Taxi drivers
- Delivery driver
- Bus driver
- Chauffeur

Fig.17 Breakdown Results of Unemployment Problem

4.2.7 Breakdown of Cost
Costs related with ADV are considered as not only limited with product of onboard systems. Additionally, costs of infrastructure systems, of R&D, of laws revision and of consumer education should be discussed, as shown in fig.18.

Cost
- Onboard systems
- Communication systems
- Road infrastructures
- Improvement of road environment
- Activities of R&D
- Revision of laws
- Consumer education

Fig.18 Breakdown Results of Cost

4.3 Analysis and Summarization of Each Disadvantage Evaluation Results (Step2-3)
As same as the advantages analysis, the disadvantages analysis could summarize as shown in fig.19. After that, the risk level for each disadvantage item should be discussed. If the risk of disadvantage relate a human life, then the risk should be settle as maximum.

Fig.19 Summarization of Assessment for Disadvantages

5. Total Assessment for Social Acceptance of ADV (Step3)

5.1 Connection of analysis between Advantages and Disadvantages
Finally, in this process, the real value for each design of ADV could be clarified. In comparing evaluation between advantages and disadvantages, weight of each evaluating item should settled. Especially, if there could be disadvantages relating human life directly, then design of ADV system should be revised in order to remove the disadvantage item.

5.2 Discussion of Availabilities of Technology to Solve the Problems
After the integration of advantage assessment and disadvantage assessment, various problems would be extracted. As the solution of the problems, various idea of availabilities of technologies should be discussed.

5.3 Discussion of Laws Development
Technological innovation could be not enough to solve the social acceptance problems. Then the discussion in laws area should be needed.

5.4 Estimation of System Cost, Social Cost and R&D Cost
For final solution of ADV design, system cost, social cost and R&D cost should be estimated, and comparing the costs to the value of ADV systems.
5.5 Selection of Global Target of ADS

Various efforts of ADV studies are conducted globally but the efforts would not be directed same target. These situation is not efficient to realize ADV in the condition of well accepted socially. After the assessment of ADV, it is favorable for ADV researcher to settle the one target globally.

6. Conclusion

The model-based methodology for social acceptance assessment of ADV is proposed. The representative example of assessment is introduced to describe the framework of assessment. The results show the possibility of the systematic assessment including various advantages, disadvantages, technological problems and social problems and will contribute to the realization of ADV future.

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