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- Automated driving technology that will transform social and industrial systems -

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A major transformation is about to take place in the automobile industry which boasts a history of 100 years. This article presents an overview of trends in automated driving and looks at the future of society where automated driving technology will be widely used. It also considers issues as well as solutions accompanying the popularization of automated driving.

1. Automated driving attracting attention as a promising solution for social issues

1.1 Social issues arising from urbanization and motorization

Although the widespread use of cars has created a wide range of social benefits, social problems attributable to urban congestion combined with excessive motorization have grown increasingly serious in recent years.

Heading the list of social problems caused by urbanization and motorization is traffic congestion. Even in Japan approximately 5.0 billion man hours are lost each year due to this problem. Moreover, approximately 1.2 million people lost their lives to traffic accidents worldwide in 2013. With one person dying in a traffic accident about every 26 seconds, there is an urgent need for measures to address this serious problem. Another serious issue is CO_2 emissions. Approximately 20% of CO_2 emissions are caused by the transport sector, with the majority of those emissions caused by motor vehicles. Responding to the problem of climate change through the use of efficient energy in cars as well as the development of electric cars and other alternatives on a world scale is essential (Table 1).

Table 1. Indicators relating to social issues stemming from urbanization and motorization

Hours lost due to traffic congestion (Japan, 2012)	Approx. 5.0 billion man hours
No. of persons killed in traffic accidents (Worldwide, 2013)	1.25 million
CO_2 emissions of the road transportation sector (Worldwide, 2013) Figure in parentheses denotes emissions in 2001.	Approx. 55.5 billion tons (approx. 4.32 billion tons)

Prepared by the Hitachi Research Institute based on data from the Ministry of Land, Infrastructure and Transport, WHO, and IEA

1.2 Caring for people with restricted movement in an aging society

In many developed countries, coping with transportation problems attributable to an aging society is also an issue requiring urgent attention. In particular, if driving becomes difficult for the elderly living in suburbs, they will have no choice but to use public means of transportation. From the viewpoint of profitability, however, there is a tendency today to cut back on public transportation routes in the suburbs. In such an environment, therefore, it is predicted that elderly people with limited options will become people with restricted movement. A possible solution to this problem is the development of cars with safety assist functions, which even the aged will be able to drive. Another solution is to establish new safe forms of public transport that cater to small numbers of people and are automated.

1.3 Development of automated driving along two trajectories: driver assist and driverless operation

The practical application of automated driving technology is attracting attention as a solution to social issues attributed to motorization accompanying urbanization and the restricted movement of people in the advent of an aging society.

The Ministry of Land, Infrastructure and Transportation (MLIT) defines automated driving as "the driving of a vehicle using a driver assist system where there is a high level of participation in the operation of the vehicle by the driver, or the driverless operation of a vehicle." There are two forms of automated driving: assisted driving and driverless operation. In 2013, the U.S. National Highway Traffic Safety Administration (NHTSA) classified automated driving according to four levels, and these have been broadly applied as a standard for explaining development principles concerning automated driving (Table 2). These levels, however, do not necessarily signify that the penetration of automated driving technology will proceed in the order of these NHTSA levels.

Table 2. Classifications of Vehicle Automation

Level 0: No automation	・The driver is in complete and sole control of operation (steering, braking, accelerating)
Level 1: Function-specific automation	・There is steering, braking and accelerating assistance but assistance is not provided for all functions
Level 2: Combined function automation	・The driver has responsibility for safe driving but there is a driver assist function for all operations: steering, braking and accelerating
Level 3: Limited self-driving automation	・The driver takes control of driving operations only when functions become limited
Level 4: Full self-driving automation	・All driving operations and monitoring of the surrounding area are entrusted to the system

Source: Information made public by the NHTSA

1.4 Automated driving contributing to traffic problem solutions

It is hoped that the introduction of automated driving technology will achieve various positive results such as alleviating and eliminating congestion on roads through the smooth flow of traffic, thereby reducing the environmental impact through reduction in CO_2 emissions, and various other outcomes including a decline in traffic accidents through the introduction of driver assist technology. Automated driving technology will also be extremely effective in addressing problems stemming from urbanization coupled with motorization, and major automakers, IT companies, governments of various countries, and universities are currently engaged in various initiatives aimed at realizing automated driving.

2. Companies, governments and universities promoting practical application

2.1 Auto manufacturers accelerating development

Auto makers began the development of automated driving systems during the 1950s. In recent years various auto makers have announced their respective dates for achieving fully automated cars and are currently stepping up development. At present these car makers are working to achieve practical application at the NHTSA’s Level 2 where the system is simultaneously responsible for the basic functions of acceleration, steering and braking on dedicated roads such as expressways. Although there are some differences in the level of focus on automated driving and approaches to the development of the necessary technologies, all automakers are proceeding with development based on a scenario for enhancing the level of automated driving in stages from Level 0 to 4.

For example, Nissan Motor is outfitting its Serena minivan with automated driving functions, and in the second half of August intends to release a stock car capable of automated driving in a single lane on expressways. This will be Japan's first stock car capable of full automation (Level 2) in steering, accelerating and braking during periods of congestion (at a low-speed range).

In October 2015, Toyota Motor Corporation gave a public demonstration to the media of its automated driving technology on the Tokyo Metropolitan Expressway, and in January 2016 established the Toyota Research Institute, Inc. (TRI) as a new enterprise for researching and developing artificial intelligence technology in the United States. During the international Ise-Shima Summit held in May 26 this year, Toyota provided a new automated driving test vehicle currently under development for automated driving demonstrations on ordinary roads. In addition to GPS and cameras, the car is outfitted with newly developed high-resolution LIDAR for image measurement of the surrounding area and distance based on the assumption that the car will be driving on ordinary roads.

In the United States, Ford has succeeded as the world's first auto maker in driving experiments of an automated driving car in diverse road environments including snow-covered roads and in unlit conditions at night. In tandem with driver assist technology, Ford is also working on the development of full self-driving technology. For the development of the latter in particular, Ford has already spent more than 10 years researching technologies. Ford is aiming for an automated driving system where the car is operated in a specific driving mode even when the driver fails to respond appropriately to requests from the system to change driving operations. This corresponds to between Level 3 and Level 4 as defined by the NHTSA.

2.2 IT companies engaging in cross-industry competition

The development of automated driving is not a challenge that is being pursued by car makers alone; IT companies have also set their sights on participating in business related to automated driving.

One company in particular that has been attracting attention in recent years is Google. Without going through Levels 1 through 3, it is aiming to go directly to Level 4 by 2017 at the earliest. Having commenced its automated driving car project in 2009, Google has already clocked up 150,000 miles in public road tests using vehicles based on Toyota Motor's Prius and Lexus as well as its own original vehicle. In May 2016, Google announced that it would partner with major U.S.-European company Fiat Chrysler Automobiles (FCA) in the development of an automated driving vehicle. The two companies are stepping up development by outfitting a minivan provided by FCA with Google's automated driving system and increasing the number of test vehicles on public roads.

There are also companies making efforts to provide new services using automated driving cars. One of these is Uber, which was founded in 2009. With the establishment of an online taxi and other vehicle dispatch service that can be accessed by smartphone, Uber at present is moving ahead with the development of technology for realizing driverless taxis using automated driving cars. In February 2015, Uber teamed up with Carnegie Mellon University in the United States, which already has a track record in the development of an automated driving car, and commenced development of an automated driving vehicle. In May 2016, Uber received a permit in the city of Pittsburgh, Pennsylvania and commenced driving trials using automated driving vehicles.

In Japan, similar tests are underway. For example, ZMP, a venture specializing in robots, has commenced joint development of a robot taxi with DeNA. The joint venture has commenced demonstration experiments in Fujisawa, Kanagawa Prefecture and hopes to initiate a driverless taxi service within a limited area by the Tokyo Olympics in 2020. This driverless taxi is attracting attention as a promising means of transportation with the potential to replace regular route buses in areas where they have been discontinued due to insufficient passengers or lack of profitability.

2.3 Governments supporting introduction for practical use

Governments in various countries are also promoting various initiatives with a view to resolving issues in the development and widespread use of automated driving cars at an early date.

Led by the Cabinet Office, the Japanese government launched the Strategic Innovation Promotion Program (SIP) in June 2014 as a cross-ministerial initiative, and one of its projects is to develop and put into practical use an automated driving system. The project aims to accelerate innovation by separating areas of cooperation and areas of competition. For example, autonomous vehicle systems (cameras, lasers, LIDAR, etc.) to be developed by private sector companies are designated as areas of competition while shared infrastructure technologies (map information, security, human machine interface (HMI), and anticipatory technology using ITS) that do not involve areas of private sector competition are established as areas of cooperation, and the government is aiming to combine them for swift commercialization of automated driving systems. In regard to the period when private companies launch these automated cars in the market, the government is aiming for a semi-automated driving system (Level 2) using infrastructure information such as traffic signal information and road congestion information by 2017, a semi-automatic system (Level 3) by the first half of the 2020s, and a full self-driving automation system by the latter half of the 2020s.

In Europe, the European Commission has been promoting R&D efforts for an automated driving system under the Horizon2020 Project, which succeeded research and development support provided by FP7 (The Seventh Framework Program) that ended in 2014. With the provision of funding from the European Commission for the major project AdaptIVe (Automated Driving Applications & Technologies for Intelligent Vehicles), approximately 30 organizations including automakers, suppliers, universities and research institutes are participating in the project, which is examining arrangements for the ideal cooperation and collaborative relationship between drivers and automated driving systems. EU countries that have automotive industries such as Germany, France and Sweden as well as the Netherlands and Finland are working to establish systems for implementing demonstration tests and public demonstrations including the designation of test bed areas.

Under the leadership of the Department of Transportation (DOT), the United States is making progress in the development of technology, and some states are currently moving ahead with measures to establish legal systems and experimental environments. In November 2014, DOT announced the ITS Strategic Plan 2015-2019, in which it revealed its research and development plans for the next five years and also commenced a demonstration project. In January 2016, the U.S. government announced in its budget draft for fiscal 2017 that it would undertake development investment of more than 4.0 billion dollars over a 10-year period to accelerate the development and promotion of safe automated driving through a pilot project. At the state level, certain states such as California are putting in place laws and regulations concerning demonstration testing on public roads. Michigan is also taking measures to establish a demonstration environment in places such as M-City.

2.4 Universities enhancing their profiles as technology development hubs

Because the areas of technology encompassed by automated driving are diverse, collaboration beyond corporate frameworks witnessed to date is essential from the viewpoint of achieving investment efficiency and accelerated development. In this regard, universities are beginning to play a greater role as venues for the development of technology in practical "areas of cooperation" where research resources of the industry are to be shared, as well as in the development of cutting-edge technology.

In the United States, the Mobility Transformation Center (MTC), located at the University of Michigan's Ann Arbor campus, and the Michigan Department of Transportation have invested approximately 10 million dollars to build a facility (M-City) for conducting driving tests for an automated driving car and connected car at a 32-acre site (approximately 13 square hectares). The joint investment of a number of partner companies makes it possible to give priority to conducting experiments on automated driving cars. At Chalmers University in Sweden, a development platform that includes a test course has been established, and various tests including collision avoidance assessment are currently underway.

In Japan, the Hokkaido Automotive Safety Technology Review Meeting was established in June 2016 to promote collaboration between automakers and research institutes including universities that have automated car-related technology. With the prefecture of Hokkaido serving as the secretariat, road administrators such as the East Nippon Expressway Company (NEXCO East Japan), research institutes including Hokkaido University, and cities and towns within the prefecture that have test courses are participating. With the collaboration of industry, government and academia, they are establishing an environment and providing information to facilitate demonstration test efforts of companies as well as R&D with a view to developing and applying advanced driver assist functions.

3. Innovation in social and industrial systems through automated driving technology

3.1 Innovation in the mobility industry

If there is a widespread consensus regarding the safety of automated driving and costs for this technology fall, it is likely that automated driving will be widely adopted through the two approaches of driver-assist and driverless car technologies in areas such as personal cars, car sharing and buses.

In public transportation, buses and taxis with car-to-car communication and road-to-vehicle communication will increase. This will facilitate determining public transportation vehicle location information and enable optimization in real time of travel on all means of transportation. In this way, people will be able to use public transportation and make transfer connections with ease.

People's use of cars will also change. If the use of driverless cars becomes mainstream, driverless automatic pick-ups and drop-offs will become widespread, and the use of car sharing will also increase. Use by individuals will increase and so too will demand for personal mobility.

Car insurance arrangements will also change. The widespread use of automated driving will result in a decrease in car accidents. Consequently, the car insurance market for individual drivers will contract but personal liability insurance for companies selling cars with automated driving will increase. The establishment of such types of insurance will then result in further expansion in development and sales of cars with automated driving.

Automated driving will not only result in a significant change in transportation arrangements but will also enable individuals to select methods of transportation to suit their requirements.

3.2 Impact on other sectors besides the car industry

Automated driving technology will also have an impact on other industries.

Agriculture, forestry and the livestock industries are promising areas for the application of automated driving. Continuous operation of automated driving of agricultural machinery used to till fields, or transport devices used to transport feed for livestock can alleviate the shortage of human labor. This technology will facilitate the scaling up of agricultural, forestry and livestock enterprises.

Use of this technology in combination with robot technology also holds promises for the future. By introducing robots with capabilities in specific tasks and movement to plants and construction sites where the human labor burden is heavy, workers will be freed from carrying heavy materials and engaging in operations in severe environments. Companies can also achieve a reduction in personnel costs and accidents causing injury or death. Likewise, there are expectations that the introduction of robots in combination with automated driving at nursing care sights will reduce the burden on caregivers and help alleviate the problem of a shortage in nurses.

In this way automated driving will ameliorate the labor shortage in areas other than transportation, and automated driving technology that raises productivity will contribute to resolving various social problems particularly in developed countries with aging populations and declining populations.

4. Social systems in an age of automated driving

Automated driving, which represents the integration of diverse technologies, has the possibility of granting freedom of movement to people and changing their relationships with motor vehicles significantly. Transportation systems which include cars comprise infrastructure that protects people's lives. To promote the widespread use of automated driving, it is important to enhance society's acceptance of this technology by ensuring not only its advanced performance but also its safety. As demonstration tests proceed, even if society recognizes the usefulness of automated driving, there is a likelihood consumers will lose confidence in this technology if a single major accident should occur.

Securing safety in automated driving must be predicated on system design underpinned by fail-safe principles and security measures. An automated driving car controls the car's operations while engaging in an exchange of various kinds of information such as information on the car's position and road information via a network in real time. Therefore, security measures based on various assumptions that take into account incidents such as the receipt of incorrect data from an external source or a virus attack via the network are essential. As electronic controls in cars develop and connections to networks expand, the importance of security measures is expected to increase more and more.

At the time of development, however, it is important to consider a balance between risk related to safety and costs for its mitigation. If developers attempt to achieve complete safety through technology alone, development costs will skyrocket and the end product will be very expensive. Therefore, in addition to technology, social systems must also be taken into consideration. Keeping down total social costs through a review of traffic rules and other matters based on the operation of automated driving cars will be of critical importance in the widespread use of automated driving.