1. Introduction

Automobiles have contributed to the development of industry and culture by expanding free and safe transportation of people and goods since the end of the 19th century. In 1885, Karl Benz of Germany succeeded in running a 3-wheel vehicle with a newly invented gasoline engine on a public road. The glorious first-ever automobile’s name was Benz Patent Motorwagen. It created the basic form of the current automobile. In 1908, the king of automobiles, Henry Ford, introduced the mass-production “Model T,” as he “wanted a vehicle as fast as a train that can run anywhere like a horse,” which created an “automotive revolution.”

And today, the environment surrounding the automotive industry is in a foregoing period of a large paradigm shift, such as diversification of power train led by electrification, global competition of autonomous driving, acceleration of “intelligent vehicles with IoT” and transformation of “ownership and use of vehicles” as can be seen in “emergence of sharing services.”

From the perspective of the global industry competition, energy, IT and automotive industries are actively partnering with each other across the borders for innovation and acquisition of new business segments while competing with each other. Even in this environment, however, we cannot overlook the fact that Tesla’s fast growth quickly achieved entry to the automotive industry from Silicon Valley, by not just building an EV but by building a vehicle platform through electrification that cannot be achieved by the conventional internal combustion engine power train. Tesla created a vehicle with very high fundamental performance that is fun, comfortable and attractive to consumers.

Also, the European automotive industry, led by Germany, is diligently working on the evolution of environment-friendly, comfortable, easy-to-drive and intelligent vehicles incorporating advanced technologies such as drive assistance and connectivity backed up by the respective state through the collaboration among the industry, academia and government. In addition, these new trends have potential to quickly expand to the automotive markets of emerging countries such as China, India and South-East Asian countries. The Japanese automotive industry also needs to be competitive to win in this paradigm shift both in global competition and competition with other industries such as IT.

These global trends can be interpreted as a solution to the compelling social problems such as global warming, traffic jams/accidents, declining birthrate and an aging population while achieving a rich and comfortable mobility society. In other words, the automotive innovations with better and smarter vehicles are the “primary units” and “driving force” for enriching the communities and the citizens (Fig. 1).

What is the CASE (Connected, Autonomous, Shared & Services, Electric) era? The integration of information and mobility has begun a paradigm change that will drastically change the ecosystem of people, cars, and transportation society, and it can be said that it is a borderless competition and collaborative era of Silicon Valley players, European car manufactures, new comers, and developing countries. Looking back on the history of automotive technology, I would like to discuss this perspective with you based on the examples of the evolution of safety, deepening driving, and mobility city systems that are the foundation of the eco-system.

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Fig. 1 Direction of vehicle innovation
“The real automobile innovation is starting now!”
“Vehicle development” and “human development” with
“integration of advancement and foundation” will make
or break is not an overstatement.

Now, let me discuss the perspective raised in the
title of this paper by looking back at the ITS (Intelligent
Transport System) activities so far. Although CASE
(Connected, Autonomous, Shared & Services, Electric)
is a term that expresses the current paradigm shift
of the automotive and IT industries well, it is not so
different from the change nurtured by the long ITS
activities aiming for the “sustainable mobility society.”
The biggest difference is the automotive industry is
forced to make a big transformation in the era of new
entrants from the IT industry of Silicon Valley such as
GAFA2), energy industry and new industries through
electrification and autonomous driving. However, this
was also included in the discussion of ITS activities, as
it expressed the importance for the automotive industry
to have a perspective of an ecosystem consisting of
people, transportation community and the use ICT
(Information and Communication Technology) for
building a rich and comfortable mobility community
(maximizing) by solving social problems (minimizing)
such as traffic accidents/jams, energy/environment and
aging society3), 4). Then, what are the real differences?
· The evolution of electrification, autonomous driving
and ICT raised the expectation that the dream of a
mobility community may come true
· It revealed the change cannot be coped with using
the conventional framework of the automotive
industry alone and a new ecosystem from both the
industrial and social system perspectives needs to be
built
· A ubiquitous and global borderless era facilitated by
the Internet made it easier for the new entrants to
play with new ideas
· Due to all of the above, the design structure of the
automobile itself, needs to be innovated

Are the above not the real differences from the
perspective of the history of the automotive industry?
This also shows the conventional structure and
mechanism of production is close to the limit and a
new S curve needs to be built for breaking the limit
representing the needs of the times. Although the
threat from IT, energy and new industries exist, the
automotive industry should not take them as the entire
picture. The real challenge is:
· if the automotive industry can transform itself, and
· if the automotive industry can take the leadership
while repeating collaboration and competition with
other industries,
aiming for a comfortable and rich mobility community.
In order for the automotive industry to take the
leadership, its own core technology is needed.

Thus, the ecosystem raised by CASE can also be
expressed as the cyber physical system (Fig. 2)5).

The cyber physical system is a system of cyber
space (virtual space) and physical space (real space)
highly integrated by ICT.

I highly expect the automotive industry to achieve
self-transformation and take the leadership of other
industries by putting the people (citizens) in the center
of mobility (Fig. 3).

In this paper, I would like to think about the mobility
community of the 21st century together with the
readers, introducing cases from the viewpoints of
“driving” and “mobility” on how the ecosystem and
cyber physical system in this mobility change in the era
of CASE.
2. Autonomous Driving; “Unity of Rider and Horse” and “Driving Intelligence Aiming for Further Safety”

2.1 What Are “Autonomous Driving” and “Driving Intelligence”?  

Information on autonomous driving technology is constantly publicized at the media, industry and state level in the world. Although with rather excessive expectation, the autonomous driving technology is promoting a big dream in the mobility community where the people have foresight of innovation in vehicles, transportation system and even information services.  

Let us track down the history of autonomous driving. Leonardo da Vinci dreamed of an autonomous driving vehicle when he thought of a mechanical vehicle. In the 1960s to 1970s, the first smart car “Stanford Craft” was conceived for investigation of the lunar surface. Long cables were equipped for a video camera and remote control which contributed to obstacle avoidance technology and higher image processing performance later in the development. However, the biggest impact on the automotive industry and society came as autonomous driving vehicles from colleges and companies participating at two DARPA (Defense Advanced Research Projects Agency) Challenges subsequent autonomous driving vehicle from Google. Google has continued the driving experiment on public roads since 2010, totaling 700 thousand miles (approx. 1,130 thousand km) by April, 2014. In Europe, state level projects such as HAVEit are making progress through a collaborative framework among industry, academia and government. In 2013, Daimler announced that it would introduce autonomous driving vehicles into the market by 2020, disclosing that its vehicle traveled autonomously on a German public road for over 100 km. Furthermore, European project PEGASUS recently created and proposed a framework for the development and evaluation process based on systematic driving scenarios. Also recently reported is the announcement of establishing a research center for autonomous driving taxis by the U.S. car sharing company Uber, and a plan of an on-demand autonomous car service from Google. As such, the competition of research and development has heated up with participants worldwide from the automotive, IT, car sharing service and logistics industry which combine engineering and business operations with the actual introduction reportedly and logistics industry which combine engineering and business operations with the actual introduction reportedly.

(1) Improvement of traffic flow (reduction of congestion/CO₂)  
(2) Reduction of accidents due to human errors (carelessness/distraction/fatigue)  
(3) Reduction of accidents due to health problems/unconsciousness  
(4) Safe driving under low visibility (nighttime/rain/snow)  
(5) Reduction of accidents by aged drivers/securing means of transportation (decline of driving ability due to physical impairment)  
(6) Improvement of comfort by reduction of driving load can be expected. However, “autonomous driving” is not necessarily “safe” all of sudden. I think there is “good driving” and “bad driving” for “autonomous driving,” as well. With the technology today, it should not be difficult to run the vehicles automatically, however, “good driving” is a different matter. Driving by an expert driver requires observation of the surrounding environment predicting possible changes based on the knowledge, experience, and understanding of his/her own vehicle’s behavior and motion characteristics with prediction of possible outcomes. The driver enjoys the value of transportation, freely, safely and comfortably by doing all of the above but it is not as easy for a machine to do that on behalf of human beings. Recognition of the surroundings is not sufficient. It requires “driving intelligence.” Also, neither people nor machines are 100% safe or trustworthy. They grew (learn from each other) by enhancing their advantages and complementing disadvantages to improve the driving quality by continuously creating “better” and “safer” driving operation under various driving conditions. Regardless of who drives the vehicle, people or machines, safe driving technique is common. Therefore, I think incorporating more “driving intelligence” into the vehicles and driving its evolution specifically is the most important challenge. In the history of mankind, the relationship between machines and people is commonplace. There has been a lot of evolution when transportation changed from the horse to vehicle; however, there are things horses can do but vehicles cannot. I do not think the vehicles have achieved the value of so-called “unity of rider and horse” such as the “safety instinct where the horse would not jump off from the cliff even if the rider instructs so and running with comfort together,” “ability of the rider, who may or may not want to drive, to communicate and act on the context of the wills of each other between the rider and the horse,” and “not to be isolated in the communication between the riders.”

In the context of CASE, this aspect of “driving” is not largely raised. In addition, we cannot ignore the development of the people (drivers) and traffic environment (infrastructure) along with the development of vehicles in the context of the relationship among the people, vehicles and traffic environment. As mentioned before, the driving technique of an expert driver
comes from the information learned under various driving conditions and knowledge accumulated over a long driving experience. An expert driver internalizes the dynamic vehicle motion reaction against the driving maneuver and holds it as “driving intelligence” in the physical model. Therefore, the driving technique of an expert driver can be understood as a cyber physical system integrating the “experience/knowledge information model” and “physical model of vehicle motion.” Is this “driving intelligence” not the important aspect where the autonomous driving technology makes the real difference?

Recognizing these challenges, I would like to step into the discussion of the evolution of “safe driving technique” and “autonomous driving with unity of rider and horse (shared control)” based on “driving intelligence,” which can be interpreted as the instinct of a vehicle, not only remaining in the generalized concept of “autonomous driving.”

The following is based on the research and development conducted since 2011 on a collaborative framework between universities and industry “Driving Intelligence System to Enhance Safe and Secured Traffic Society for Elderly Drivers”7) which is the theme adopted by the “Japan Science and Technology Agency (JST) Strategic Innovation Promotion Program (SIP)” and my own view.

2.2 Driving Intelligence Aiming for Further Safety

2.2.1 Driving Support System and Autonomous Driving Technology

The safe driving technology has evolved from collision safety to preventative safety. The recent idea of “integrated safety,”8) which covers the entire safety phases from the normal driving phase to collision and rescue/emergency response phase for reviewing and responding is an important philosophy showing “there is no compromise for safety.” With this philosophy, adoption of a driving support system that recognizes the driving surrounding environment and obstacles using sensors such as cameras and radar expanded very quickly. Devices such as collision damage reduction/preventative automated brake systems are deployed in many products as their benefit is easily recognized and its adoption is recently expanded even in light vehicles under the name of AEB (Automated Emergency Brake). This way, the capability of accident avoidance is a little over a second before collision, such as rear-end collision, has greatly improved. On the other hand, systems for reducing the driving load during normal operation have been deployed, such as the ACC (Adaptive Cruise Control), LKA (Lane Keeping Assist) and LDW (Lane Departure Warning (& Prevention)). From the safety standpoint, driving phases consist of the “normal driving” phase for smooth driving without any risk and the “emergency avoidance” phase, which is a few seconds before potential collision and with increased potential/apparent risk. In the former phase, it is necessary to drive with caution while predicting potential risks as the driving schools often teach with “risk predictive driving” (Fig. 4). So far, the driving support system has been effective in “normal driving” and “emergency avoidance” phases. As the autonomous driving technology evolves, we must not overlook the technology of “look-ahead driving” that corresponds to the risk increasing phase. Also, as mentioned earlier, since 90% of the traffic accidents are caused by human errors, the evolution of driving support systems to deal with the various causes, such as elderly drivers, distraction, health problems, distracted, congestion, etc. is expected. However, adding individual systems will not be effective. It should be necessary to complement driver errors by the autonomous/intelligent driving systematically.

Fig. 4 Concept of risk phases for preventative safety (SIP)9)

2.2.2 Driving Intelligence with Risk Prediction Capability

Now, how can we specifically capture the driving intelligence? First, it is essential to “observe well” the surrounding environment, namely, improve the ability of “recognition” with sensing technologies. In addition, it is necessary to create the basic drive planning ability such as generating the path to the destination from the recognized information10) and pass around the stopped vehicles. In addition essential drive planning and risk prediction intelligence will be required by looking ahead and anticipating risks (Fig. 5).

Fig. 5 Layered structure of risk predictive control (SIP)11)
Risks include apparent risk such as a bicycle or pedestrian who is visible but “may” change the behavior in the next instance, and potential risk such as a pedestrian who is hidden and may jump out from behind a stopped vehicle. There are two important points for making the risk prediction technology. The first is the model to define the possibility of collision a few seconds away while running and to physically express the present margin toward the risk. There are some methods such as the potential field, but this is an important model expression for generating the optimum driving path with smaller risk and control of the vehicle speed. The second is the learning process based on the experienced running information. The ontological approach based on rich information is also necessary in order to determine the risk from the apparent conditions. Building prediction model’s integrating the physical model and information model is a new challenge for the automotive industry. The “near-miss incident data” currently accumulated at Tokyo University of Agriculture and Technology is very useful as a source of information. Since this is the information source determining risk events such as “emergency brake was applied even if it did not lead to accidents,” learning the data may lead to risk prediction. As described above, it is indispensable to implement the intelligent behavior of people, such as feeling “somewhat risky” from general observation and slowing down, to the machine (vehicle) for evolution of safety and technical challenge called autonomous driving.

Fig. 6 shows the physical model expressing the risk as the potential field (hereafter, “risk potential”) in the SIP project. By making the space information recognized by various peripheral monitoring sensors risk potential, the risk image of driving environment such as the parked vehicles can be continuously presented as the physical expression. Furthermore, this potential field facilitates driving control since it can optimize the target course and speed (I am omitting the detailed explanation. Refer to the reference for more information).
We have simulated intersections and jumping-out of pedestrians and bicycles on public roads of approx. 10 km around the Kanagawa Institute of Technology and built a virtual model considering the LHP and Rv indices. This dynamic simulation result shows a reduction of near-miss incidents to approx 1/4 (total of 7,486 near-miss incidents) and a reduction of accidents to approx 1/50 by the introduction of risk prediction control (slowing down by risk predictive driving). This result indicates the difference between “autonomous driving to apply brake after observation (recognition)” and “driving intelligence of slowing down by looking ahead for something jumping out from the visible environment.” This kind of simulated effect prediction does not have enough credibility, yet, as the history of weather forecast shows. However, it shows a direction of risk prediction technology both as the system control technology and as the digital twin virtual validation technology integrating the “information model” and the “physical model.” This framework that we could build this time is important but we have to note that this database might not be effective in the area/country where the traffic environment is different, similar to the fact that the people familiar with the area can drive effectively. Our challenge is how to build near-miss incident database for each community and how to structure them.

2.4 Autonomous Driving with Unity of Rider and Horse (Shared Control) (17)-(19)

The machines are only used by the people when trusted. As mentioned earlier, the people may want to drive or may not when tired or under monotonous situation. Elderly people feel uncomfortable driving, recognizing poor physical conditions. Enabling them to drive worry-free to the destination should be the role of the intelligent machine, not taking away the driving privilege from the elderly people. The benefit of cars is not only providing means of flexible transportation but also driving pleasure. Use of machines by people has an aspect of stimulus to the instinct where the people become active and motivated. Recently, “use of information” significantly expanded through the use of smartphones. If the information provides value for “knowing,” “things” have value “to be seen, touched and felt.” The question is not to determine which is better, but the important point they both offer in common is if the context the machines provide can be understood by the people who use them (or easily understood). This does not immediately jump into the discussion of HMI (Human/Machine Interface) or driver monitor, but rather, we have to check if the machines provide the outcomes (performance) that meet or exceed expectation of the people who use them (this is the baseline for the trust). The machines should predict the result (performance), provide the context of their action to the people and be understood. In this context, the smartphones are ahead. The vehicles are still behind the curve. By providing the road conditions and recognition that the machines determine optimal as rational as possible to the people and expressing them through the steering wheel, acceleration and braking which the people can touch and feel while the frontal view that the people can see and understand, the machines can become closer to the horses. It is imperative not to add new interfaces and increase the load of driving. Can the context of driving be firmly grasped and communicated to the people? This is also what is expected from the intelligence of autonomous driving (i.e. driving intelligence).

An example of the research achievements of SIP project is shown in the following. Fig. 9 shows a conceptual diagram of Haptic Steering Shared Control (10). It aims for guiding the vehicle to a better course trace by applying the difference between the steering operation modeled after an expert driver and steering operation of a real person to the steering torque reaction force. It revealed that this control improves both traceability of the model course and smooth operation (Fig. 10) (14), (20), (21).
I have discussed “driving intelligence aiming for further safety” and “autonomous driving with unity of rider and horse” in the evolution of autonomous driving technology as my expectation. I welcome participation of those who share my view in this discussion.

3. Connected; Mobility Ecosystem Connected by Information

3.1 Overview
Now, let us think about the transformation of transportation system as the ecosystem of people, vehicle and traffic environment. That is, MaaS (Mobility as a Service). The possibility of service businesses is unlimited in the cyber physical network where information and mobility are integrated. Services to use multiple means of transportation in an integrated fashion are beginning and expected to grow worldwide. In Finland and Singapore, collection of traffic information and creation of database for dynamic communication are led at the government level. The initiatives at ITS include solution of mobility divide, that is, safe mobility and active life support of elderly and disabled people who are vulnerable road users, and revitalization of local communities and improvement of QOL (Quality of Life) of citizens. Therefore, the concept of “provision of equal mobility to everybody” is also important.

The above is an example focused on the information/software aspects but formation of ecosystem as an infrastructure that includes IoT and physical space is also important as the information and mobility are integrated. Let me introduce a research and development project in Singapore, “TUMCREATE,” as an evolution of mobility from transformation of transportation system.

3.2 TUMCREATE
A project of Technical University of Munich, TUMCREATE (TUM: Technical University of Munich), adopted by the CREATE (Campus for Research Excellence and Technological Enterprise) program of Singapore’s National Research Foundation is a good research example that shows a new mobility community.

This project is joined by Singapore’s NTU (Nanyang Technological University) and thus contributing to the development of young Asian engineers. The first phase was conducted from 2010 to 2016 with the theme of “The Center for Electromobility in Megacity” and the second phase is being conducted from 2016 to 2021 under the theme of “Towards the Ultimate Public Transport System.” Over 100 engineers and researchers will participate in this project from both universities and the professors from the Technical University of Munich are also stationed in Singapore dedicated to 5 years of research.

In the first phase, NTU’s engineers learned the architecture of vehicles including package design as the foundation of automotive engineering, in addition to building an EV. They also digested the foundation of the electric motor system such as the design of battery pack and test bed and fabricated a research vehicle taxi EV suitable for megacities in South East Asia, called EVA (Fig. 11).

In addition, they conducted simulation of the traffic conditions in Singapore, as well as to the simulation of the battery management in the vehicle. They even built a data management system for optimization of driving and battery charging.

The research theme of the second phase is traffic congestion, energy and security in Singapore, which is precisely the solution aimed at problems of megacities in the new ecosystem proposed by the ITS activities.

First, the mobility called SRT (Semi Rapid Transit) System is planned, which uses units of 30 person capacity to form a flexible caravan of autonomous driving. This is a mobility capability aimed for increased efficiency in urban transportation, between MRT (Mass Rapid Transit) System which is high speed/high capacity with sparse passengers and a bus service which is slow and low capacity (Fig. 12).
Naturally, the electric vehicle with the technology developed in phase 1 is used. The SRT System is characterized by the following, in addition to the service offering of seamless use of multiple means of transportation (mobility X).

- Multifunctional capability by autonomous driving as the module
- Clean urban environment by electric vehicles
- Dynamic and flexible passenger transporting capability up to 10 units (300 passengers) in a caravan during peak hours
- Quick response to demand reducing wasted time
- Quick loading/unloading at the SRT stops

Next, the SRT-MODULE is not a stand-alone project but a component of an integrated ecosystem with SRT-CENTRAL, SRT-INFRASTRUCTURE, SRT-CONNECT and SRT-POWER (Fig. 13, 14).

The SRT vehicle unit is designed with user-friendly features, such as an air curtain to contain the conditioned air in the vehicle while loading/unloading, all wheel independent steering mechanism for a small turning radius and easy parallel parking (Fig. 15), low-floor and guidance technology with road projection for easy access, adopting many novel ideas.

They can be evaluated/designed on the virtual space using VR (Virtual Reality). The most spectacular point is that they have built a dynamic simulation of the entire city of Singapore, called CityMoS (Fig. 16).

This is the system with layers of power system, sensor network and a traffic system for the entire city not only providing simulation (virtual world) but also actual data sensing (real world), so it is built as a cyber physical system. In other words, the city-state of Singapore itself, as the “Cyber City,” has become an intelligent system.

As an advisor of this project, I am impressed with the young engineers of TUM and NTU who are excited and confidently working on their respective R&D subjects. Post doctoral researchers, doctors, professors and engineers of NTU from the international alliance are increasing their capabilities through automotive design and manufacturing while acquiring a high skill set of the cyber physical system. The level of these R&D activities is equivalent to forefront R&D activities at large corporations. Some companies seem to participate in the actual manufacturing process but most of the basic design is decided by this project. Also, the project offers a powerful human development opportunity for young engineers.

3.3 Disaster-Resilient Ecosystem for Japan

In this Chapter, I have only mentioned good projects from the overseas but now I would like to mention universal concepts originated from Japan which (in my opinion) should also work worldwide.

In the era of Heisei, Japan was struck by many disasters and many people had a bad experience.
However, the Japanese culture had strength to overcome these disasters. Based on these lessons, we have to build an ecosystem suitable for Japan in the era of Reiwa, which is highly active in normal period and resilient to disasters.

In the Great East Japan Earthquake of March 11, 2011, the entire nation of Japan grieved over the death of many people. I would like to express my deepest sympathy to the deceased and encourage the people who are working hard in the aftermath.

Personally, I also experienced the earthquake on March 11, when I was holding a conference in Sendai. I experienced the infrastructure risk firsthand. An experience of loss of social infrastructure with information completely blocked, energy risk of electric power and gasoline, disruption of means of transportation, lack of food and water, etc. The following is an unofficial proposal we made to the government and business community, which is based on my own note of lessons I learned as one of the citizens working on the mobility industry and contribution from colleagues.

3.3.1 Lessons from the Experience of Infrastructure Risk
- Mobile phones did not work as the base stations were dysfunctional.
  → Internet and WiFi spots are effective. Distribution-optimized ad-hoc base stations are needed.
- It was unfortunate that a Prius generator could not be used for 12V output. (Toyota provided this feature soon after the disaster.)
  → Electrification means having optimum battery capacity; yet, having generators is also important. Especially a multi-fuel generator.
- Real-time mobility connection information is required on how to coordinate public transportation, automobiles and other mobility modal.
- Autonomous distributed power management system is also required, not only overall optimization such as the power grid.
- It is important to “have the ability to communicate with strangers,” “take action when scared” and “believe in one’s own sense of risk.”

3.3.2 Proposal for Disaster-Resilient System
- Locally generated/locally consumed distributed energy community
  → Autonomous management of local power system for energy saving and efficient use based on management of local energy information such as a stationary battery. Control of demand and supply balance with the power grid by dynamic pricing during normal operation.
- Building autonomous and distributed mobile wireless communication network
  → Use vehicles as the temporary wireless tandem stations for ad-hoc communication network using WiFi functionality during disasters or in remote areas, as a limited emergency communication system.
- Multi-fuel range extender
  → Effective during normal and disaster periods.
- Automatic driving system for remote control and autonomous driving
  → The questions of security need to be addressed, but remote control driving is effective during disasters. Vehicles with ability to run on bad terrain such as SUVs are also effective.

Some of the above have made good progress but having built the cyber physical ecosystem with autonomous and distributed system in addition to overall optimization system must be particularly important for the ecosystem of Japan where many disasters strike.

4. Summary
In this paper, we have discussed the evolution of advanced automobile technologies toward the era of CASE and evolution of ecosystem of people, automobile and traffic environment, although the discussion may have been generalized towards the end. For example, the discussion included much of my personal views, which may not reflect the trends of the time objectively. We are certainly in the midst of a once in a century paradigm shift and we should have a sense of urgency as global competition intensifies; however, this change is an inevitable result of evolution and is also important to have originality in our vision and ideas based on the Japanese culture and history, for the requirements of the mobility society and automotive technologies. I believe that these views and ideas will have a positive global impact.
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1978 Graduated from Mechanical Engineering, Faculty of Science and Engineering, Waseda University
1978 Joined Toyota Motor Corporation
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2013-present Advisory Committee Member, TUMCREATE, a Germany-Singapore International Partnership Project
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1992 FISITA Paper Award, Development of Vehicle Integrated Control System
1998 Japan Society for the Promotion of Machine Industry, 31st Minister of International Trade and Industry Award “Development of a sideslip prevention rolling stock stability control system”
2009 The US Government Award from NHTSA for Special Appreciation for contributions to the development and popularization of safety technology
2016 The Japan Society of Mechanical Engineers, Transportation and Logistics Award for Achievement