Second Phase of Cross-Ministerial Strategic Innovation Promotion Program
— Innovation of Automated Driving for Universal Services (System and Service Expansion)

Study of the Impact of Automated Driving on Reducing Traffic Accidents and on Others

Report (Summary)

May 2021

The University of Tokyo
Doshisha University

ITEC
Institute for Technology, Enterprise and Competitiveness

Objective of study

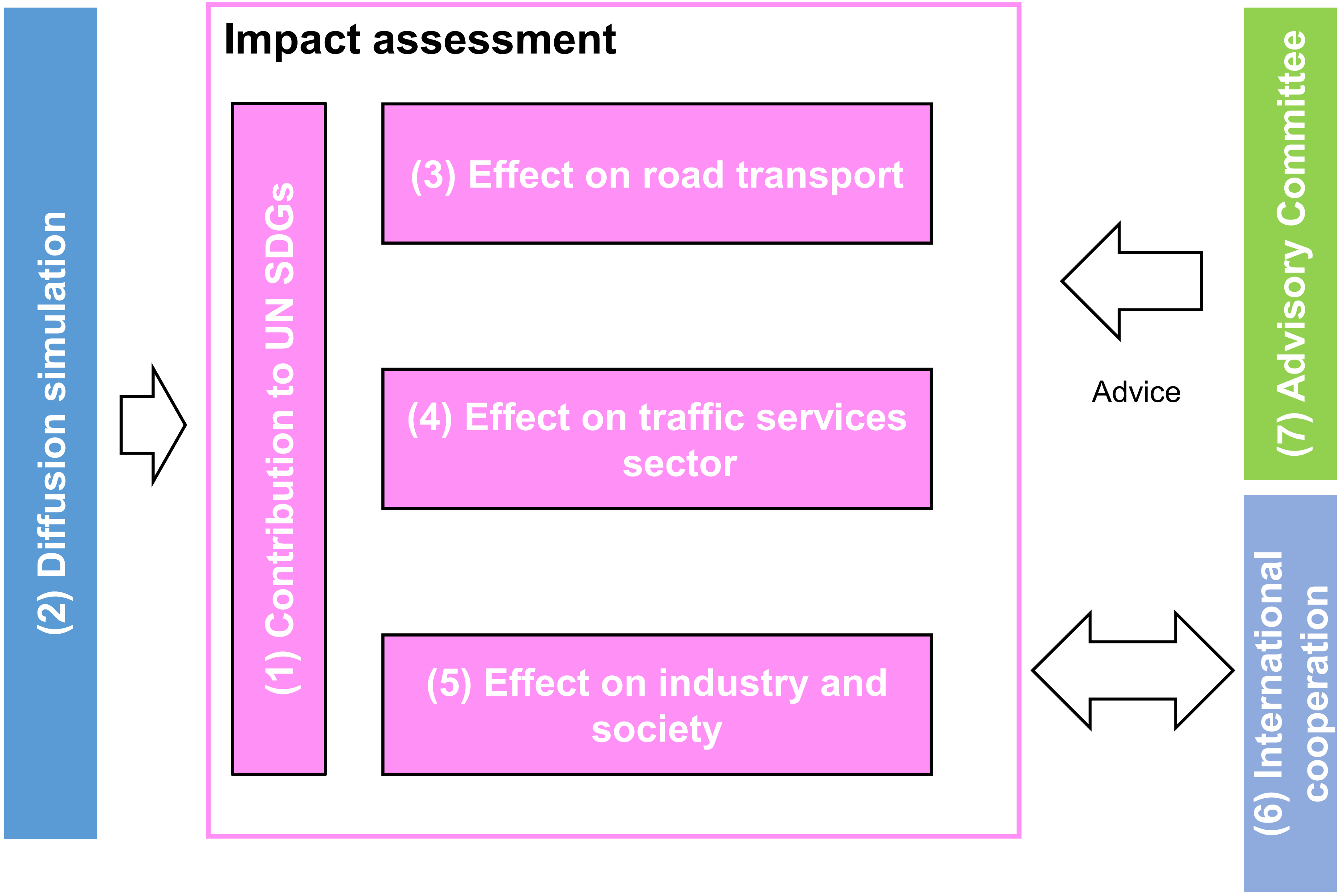
Research and development plan for Second Phase of Cross-Ministerial Strategic Innovation Promotion Program — Innovation of Automated Driving for Universal Services (System and Service Expansion)

Commercial development and increased diffusion of automated driving (AD) vehicles will help to reduce traffic accidents, alleviate traffic congestion, ensure mobility for vulnerable road users, resolve the driver shortage and reduce costs in logistics and transport services, and resolve other social problems. The aim is to achieve a society in which everyone is able to enjoy a high-quality life.

Quantification and monetary valuation of impact (benefits and potential risks) → Basic references for fostering social acceptance

Focus on differences in impact caused by governmental policies and/or manufactures' launching methods → Use in corporate management and policymaking

Overall configuration of study



Study items

(1) Relevance of AD to SDGs

(2) Simulation of AD vehicle diffusion

(3) Effect on road transport

i. Estimation of effectiveness in reducing traffic accidents
ii. Estimation of reduction of traffic congestion and reduction of CO_2 emissions

(4) Effect on traffic services sector

i. Ensuring mobility for vulnerable road users and in depopulated areas and other locations with poor access to transport
ii. Reduction of costs and resolution of driver shortage in logistics and transport services
iii. Change in ownership and usage of vehicle, and the structure of consumers' choice

(5) Effect on industry and society

i. Effect on whole automobile industry due to change in vehicle ownership structure and other effects
ii. Contribution to growth of the total factor productivity of the Japanese economy

(6) Formation of organization for international cooperation

(7) Convening of Advisory Committee

1. Relevance of AD to SDGs

<Outline>

To organize the relevance of AD to the UN's Sustainable Development Goals to establish a clear vision of how self-driving cars can help us build sustainable societies.

<Method>

To organize the relevance based on the discussion within the Advisory Committee on the Relevance of AD to SDGs.

Advisory Committee on the Relevance of AD to SDGs

1) Meeting dates and venues:

April 5, 2019, 1:00 - 3:30 PM, at Kambaikan meeting room of the Institute for Technology, Enterprise, and Competitiveness, Doshisha University

(Individual interview with Dr. Hiroto Inoi, member of the advisory committee, was conducted on
April 23, 2019, 1:00 - 2:30 PM, at Kambaikan meeting room of the Institute for Technology, Enterprise, and Competitiveness, Doshisha University)

2) Advisory Committee members (without honorifics)

Name	Affiliation and Position
Chairman Masanobu Kii	Professor, Faculty of Engineering and Design, Kagawa University
Member Tateo Arimoto	Visiting Professor, National Graduate Institute for Policy Studies (GRIPS) / Principal Fellow, Japan Science and Technology Agency (JST),
Hiroto Inoi	Associate Professor, Faculty of Sustainable Design, Department of Civil Design and Engineering, University of Toyama
Yasuhiro Shiomi	Associate Professor, College of Science and Engineering, Department of Environmental Systems Engineering, Ritsumeikan University
Keii Gi	Senior Researcher, Systems Analysis Group, Research Institute of Innovative Technology for the Earth (RITE)
Keisuke Matsuhashi	Head, Center for Social and Environmental Systems Research（Environmental Policy Section), National Institute for Environmental Studies

Classifying impact (1)

1) Direct and indirect impact

Direct impact : Effects exerted by AD, through the changes in mobility they enable, on SDG goals and targets.

The **Global Mobility Report 2017** prepared by Sustainable Mobility for All defines four sectors of sustainable mobility: *universal access, efficiency, safety,* and *green mobility.* Following this guidance, we considered potential impacts on each of the four sectors—*universal access, system efficiency, safety,* and *green mobility*—as well as synergies and tradeoffs arising between them.

Indirect impact (ripple effects): Effects exerted by AD—through the direct impact they have on SDG goals and targets—on other SDG goals and targets. We identify three sectors: (1) Increased income and reduction of disparities, (2) improved sanitation, and (3) expanded educational opportunities.

Classifying impact (2)

2) Short-term and long-term impact

Short-term impact refers to factors influencing SDG goals and targets that will emerge when SAE level 1 or level 2 diffuse into society. This should be more or less achieved by 2030, the target year for achieving SDGs.

Long-term impact refers to factors influencing SDG goals and targets that will emerge when SAE level 3 or level 4 ADs with sufficiently extended ODD, or SAE level 5 ADs, diffuse into society. This will be difficult to achieve by 2030.

3) Three categories of ADs for consideration of long-term impacts

For consideration of long-term impacts, it is useful to identify three distinct categories of applications for ADs: (i) Logistics / mobility services, (ii) Privately owned vehicles, and (iii) shared mobility.

Conclusions (1)

- Through both direct impacts—including associated synergies—and indirect impacts, AD will make wide-ranging contributions toward achieving SDG goals and targets.
- On the other hand, there are several potential negative impacts, and tradeoffs may arise as described in the following examples:

1) Societies may suffer a decrease in resilience at the time of disaster, which may have negative impacts for targets 11 and 13.

→It is essential to promote the development of management technologies for AD vehicles.

Conclusions（2)

2） If passengers' AD cars are mainly privately owned, a modal shift toward automobile transit and urban sprawl is expected.

If shared mobility becomes widely adopted, a modal shift toward automobile transit in urban transportation is expected.

These developments would have negative impacts for goals 3, 7, 8, 9, and 11.

→ To introduce an economic framework in which external diseconomies are internalized.

→ Other initiatives are needed, such as improved connectivity between AD vehicles and other modes of transit.

2 Simulation of AD vehicle diffusion

<Outline>

- To establish a diffusion simulation model of AD vehicles to use the simulation results as common data for various impact assessments in this project.
- Two types of simulations are conducted:
  - Dynamic model : Simulation to estimate the diffusion of AD vehicles up to SAE Level 4, where the timing of technology realization is foreseeable to some extent,
  - Static model: Simulation to estimate the diffusion of AD vehicles assuming a situation where driverless AD vehicles (equivalent to SAE levels 4 or 5) are realized.

<Method>

A) Dynamic Model : Simulation of AD vehicle diffusion up to SAE Level 4

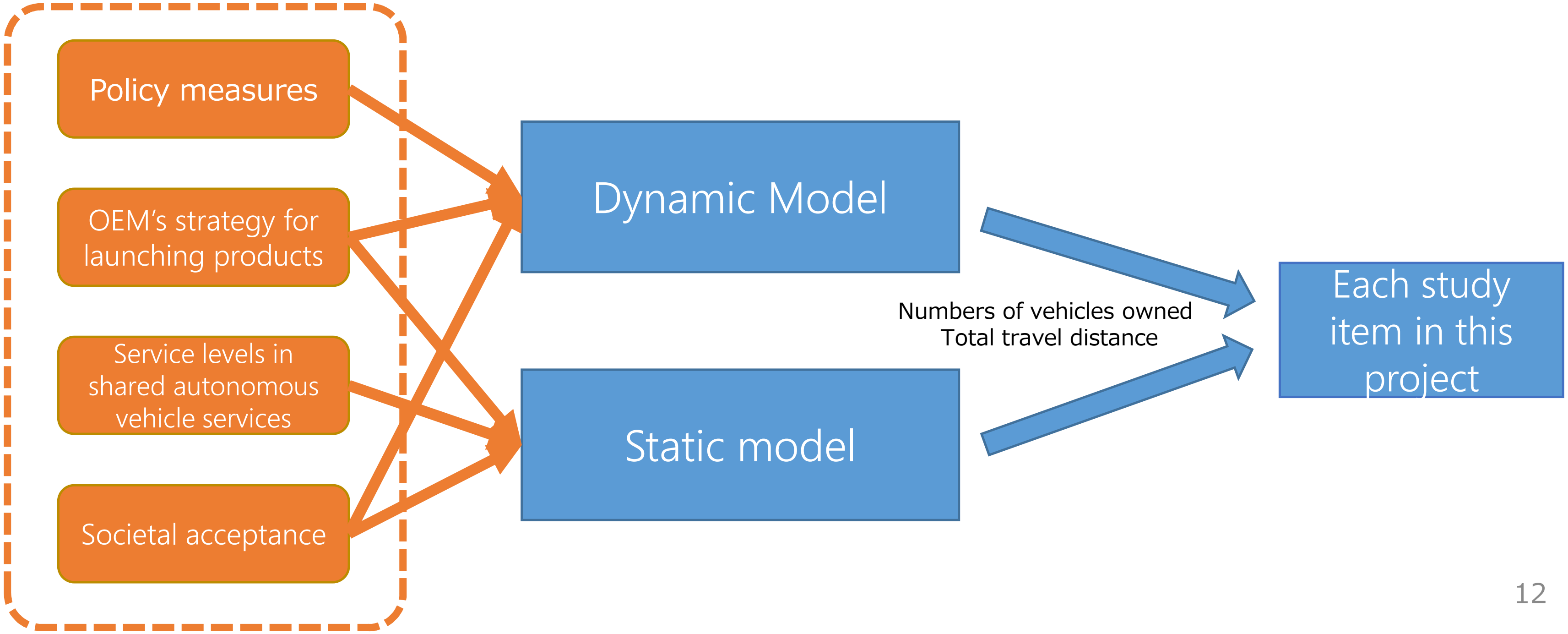
- To estimate the number of vehicles owned in the future based on the future estimates of GDP and population.
- To set a market launch date for AD vehicles in each automated driving category.
- To estimate the percentage of vehicles in each automated driving category among new vehicles based on “cosumer’s choice pertaining to automated driving technology" and "cost reduction by experience curve effect”.
- To estimate the number of vehicles owned and travel distance for each automated driving category

B) Static model: Simulation of impacts from introduction of driverless AD vehicles.

- To assume a society where driverless AD vehicles (equivalent to SAE levels 4 or 5) are realized and a transportation system that utilizes these vehicles is available,
- To estimate the use of each mode of transportation based on the “consumer's mode choice model “,
- To estimate the number of vehicles owned and travel distance based on the use of each transportation mode.

Objectives of simulation

- Simulation results are used as common data for various impact assessments in this project.
- Impacts from the following factors on market diffusion of AD vehicles can be evaluated:
  1. Policy measures（economic incentives, mandatory installation of automated-driving devices, introduction of new types of driver licenses with relaxed conditions on license holders),
  2. OEM's strategy for launching products (when to launch into markets, at what price),
  3. Service levels in shared autonomous vehicle services（usage fee, waiting time）,
  4. Enhancement of societal acceptance.



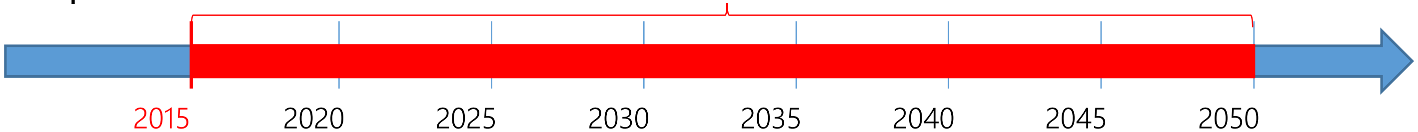
A) Dynamic Model : Outline

1. Classification of simulation

Category in this study	Outline of simulation method	Outputs
Privately owned vehicle	To use results of online survey to model consumer's technology-related choices	Numbers of vehicles owned New vehicle registrations Traffic volumes
Mobility services	Ratio of each category of AD vehicle is set referring to privately owned vehicle	
Logistics services	To use results from the study *(4)- **ii** . Reduction of costs and resolution of driver shortage in logistics and transport services**	

2. Simulation period

Simulation period: 2015 - 2050, data output at 5-year intervals



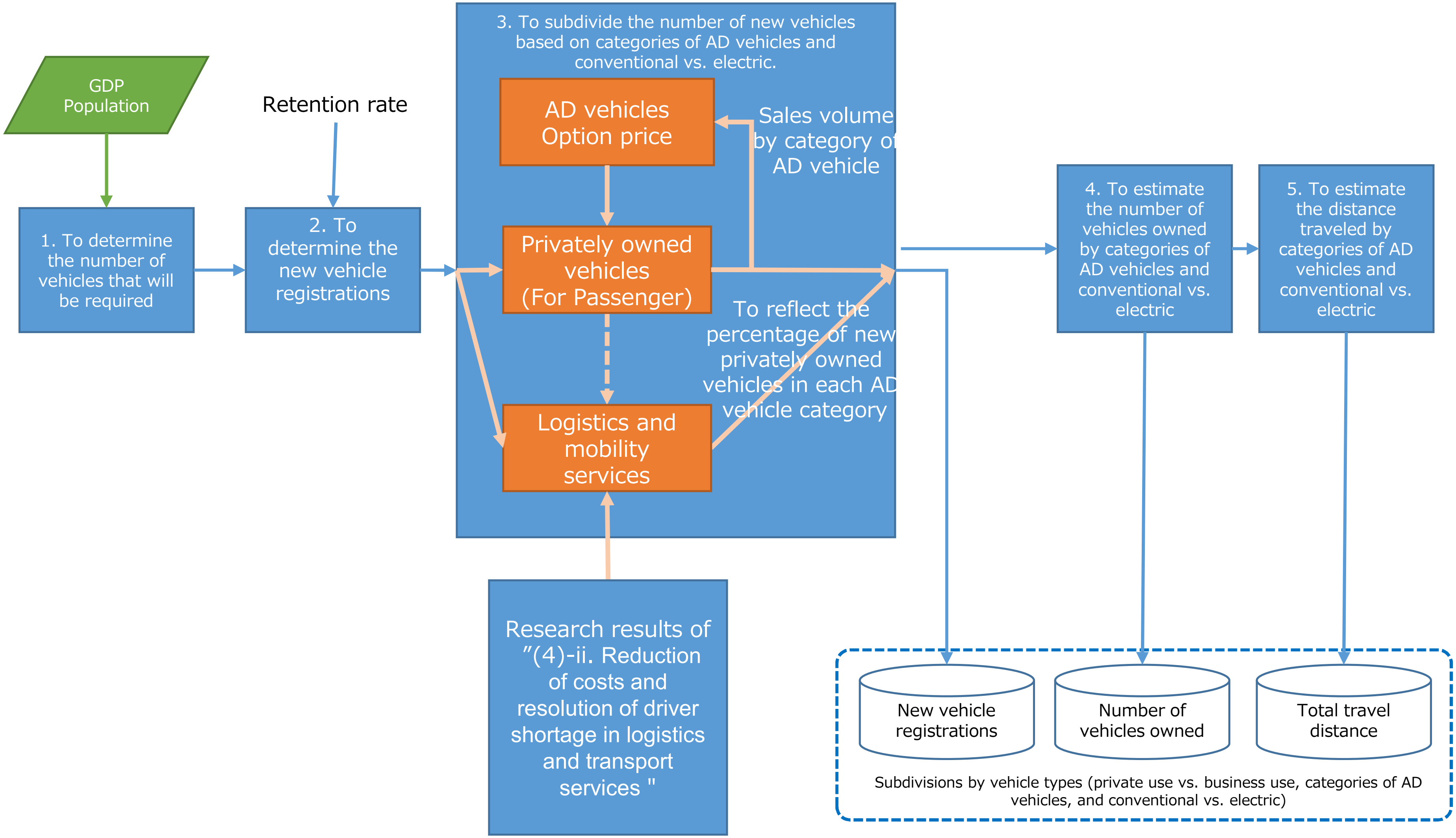
3. Categories of AD vehicles considered in the dynamic models

Category	Highways	General roads	Compatible technologies and others
C0	SAE Lv. 1 or less	SAE Lv. 1 or less	Level under C1.
C1	SAE Lv. 1 Driver assistance	SAE Lv. 1	Equipped with all the following four devices ・Collision-damage-reducing brakes, ・Acceleration limiters for accidental accelerations (due to driver error), ・Lane-departure warning system, ・Car distance warning system.
C2	SAE Lv. 2 Partial automation	SAE Lv. 1	In addition to C1: ・On highways, lane keeping systems (LKAS) + adaptive cruise control (ACC), ・Automatic lane changing on highway.

Category	Highways	General roads	Compatible technologies and others
C3	SAE Lv. 3 Conditional automation	SAE Lv. 2	In addition to C2: ・Lv. 3 on highways, ・Lv. 2 on general roads.
C4	SAE Lv. 4 High automation	SAE Lv. 3 on major arteries and thoroughfares	In addition to C3: ・Lv. 4 on highways, ・Lv. 3 on major general roads, ・On general roads, take-over requests (TORs) for driving operations will be issued in response to system demand.
C5	SAE Lv. 4 High automation	SAE Lv.4 on major arteries and thoroughfares	In addition to C4: ・Lv. 4 on major general roads, ・Take-over requests (TORs) will not be issued.

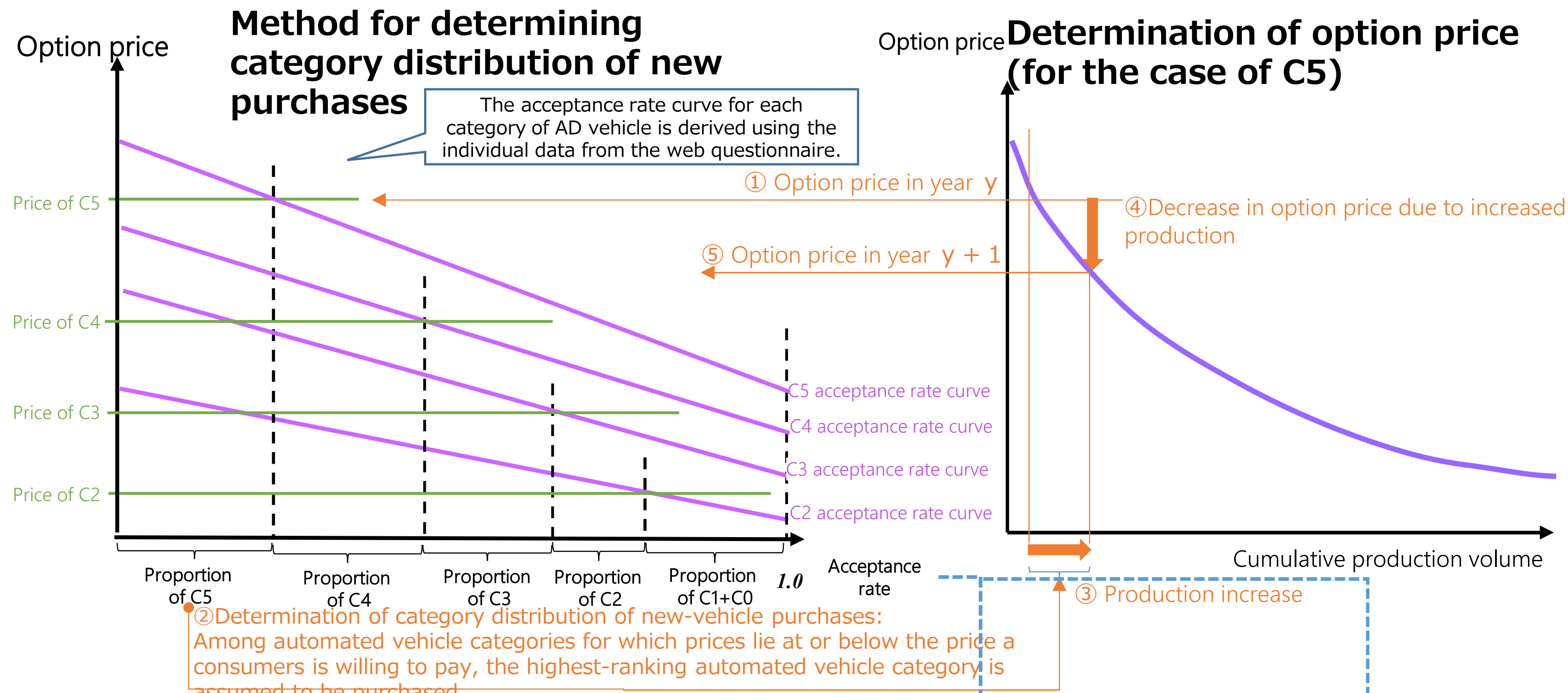
*The AD vehicles used to address the driver shortage in logistics and transportation services are equivalent to category C5.

A) Dynamic Model : Outline

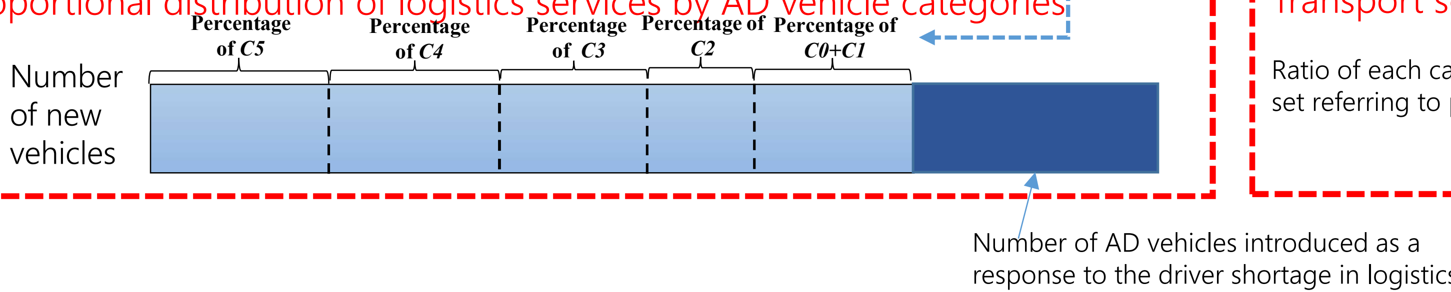


A) Dynamic Model: Distribution of AD vehicle categories among new privately owned passenger cars

Distribution of AD vehicle categories among new privately owned (passenger) cars



Proportional distribution of logistics services by AD vehicle categories



Transport services:

Ratio of each category of AD vehicle is set referring to privately owned vehicle.

A) Dynamic Model: Market release times and initial option prices by category of AD vehicle

- The year of market launch, the initial option price, and the cost reduction (progress ratio) due to the experience curve effect are set as follows.

*Progress ratio: Production cost ratio when cumulative production volume has doubled

AD vehicle category	Year of market launch				Privately owner car (For passenger)	
	Logistics services	Transportation services		Privately owned car	Initial option price (10,000 yen)	progress ratio*
		Ride share	For passenger	For passenger		
C2	2021	2022	2019	2019	41	0.9
C3	2023	2023	2020	2020	70	
C4	2025	2025	2025	2025	81	
C5	2030	2030	2030	2030	93	

5 years after C4

Determined based on "Public and Private ITS Initiative / Roadmap 2019" and "Action Plan for realize the Automated Driving Version 2.0" (Panel on Business Strategies in Automated Driving, March 30, 2018)

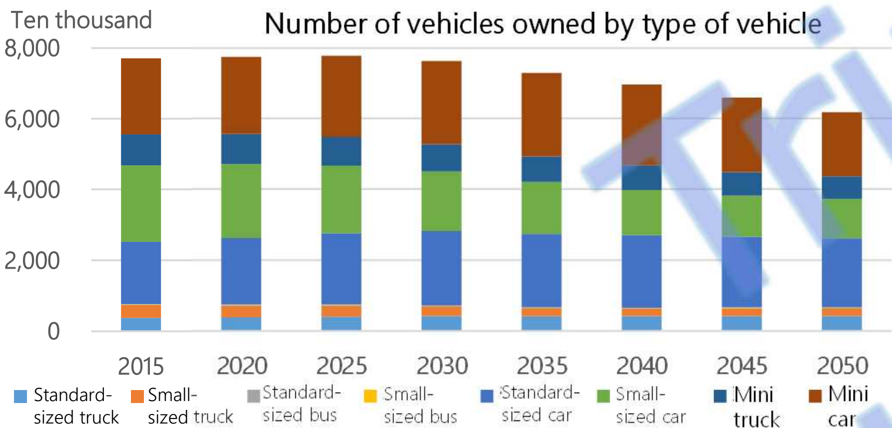
Determined in reference to Xavier Mosquet et. Al, "Revolution in the Driver's Seat: The Road to Autonomous Vehicles" (Boston Consulting Group, 2015)

Determined based on experience curves for automated braking systems

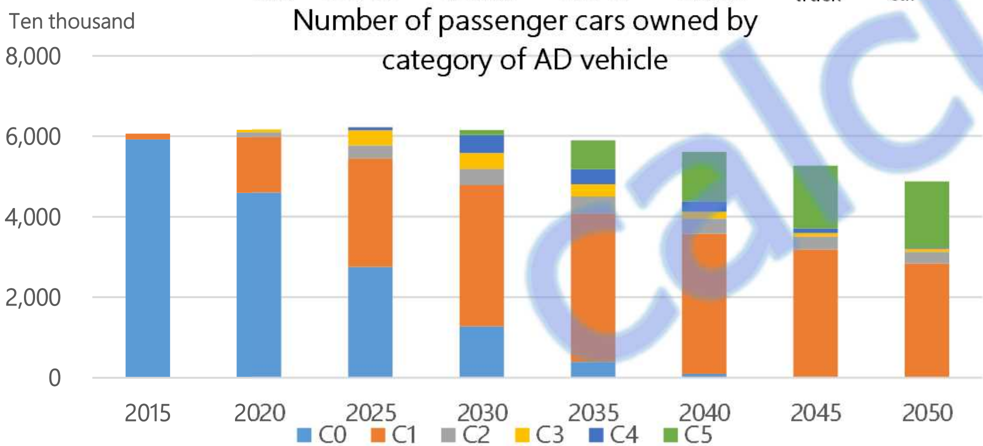
A) Dynamic Model: Base case simulation results (number of vehicles owned)

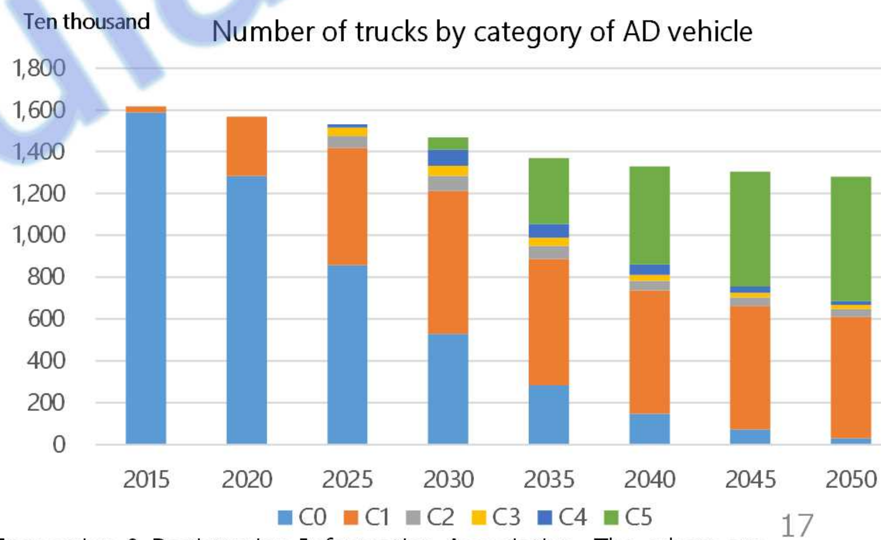
The number of vehicles owned is calculated as a base case to compare the effects of various measures.

Future population estimates: National population estimates for the medium birth and death rates, the National Institute of Population and Social Security Research, 2017
Future estimates of GDP: Case III in "Current Status and Outlook of Finances for National Pension and Welfare Pension - Results of Fiscal Verification in 2019", Ministry of Health, Labour and Welfare, August 27, 2019



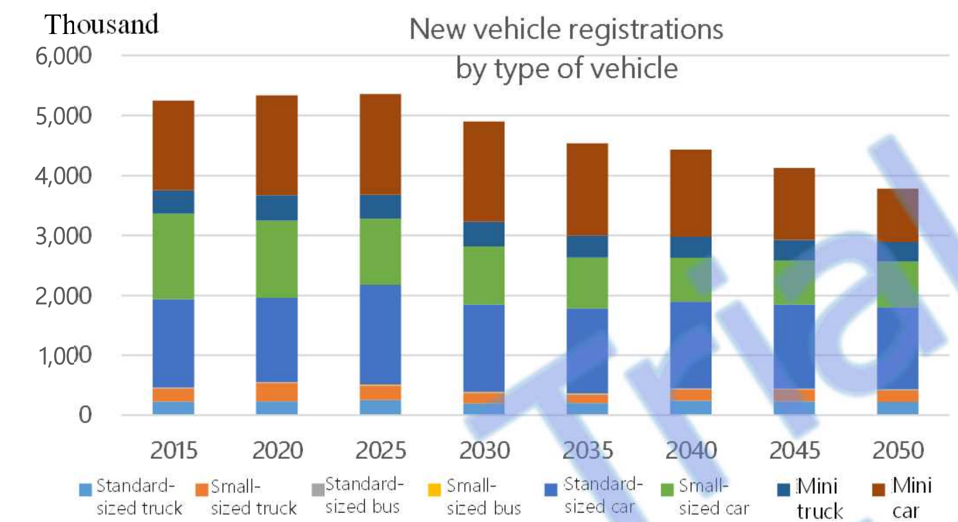
- According to this estimation, the share of manual-driving vehicles (category C2 or lower) in the total number of passenger cars owned will still be more than 50% in 2050.
- In trucks, AD vehicles to address the driver shortage (C5) will account for 26% of the number of vehicles owned. Driver shortage will be a major factor in the diffusion of AD vehicles. These results are obtained using the estimates of 4－ii .





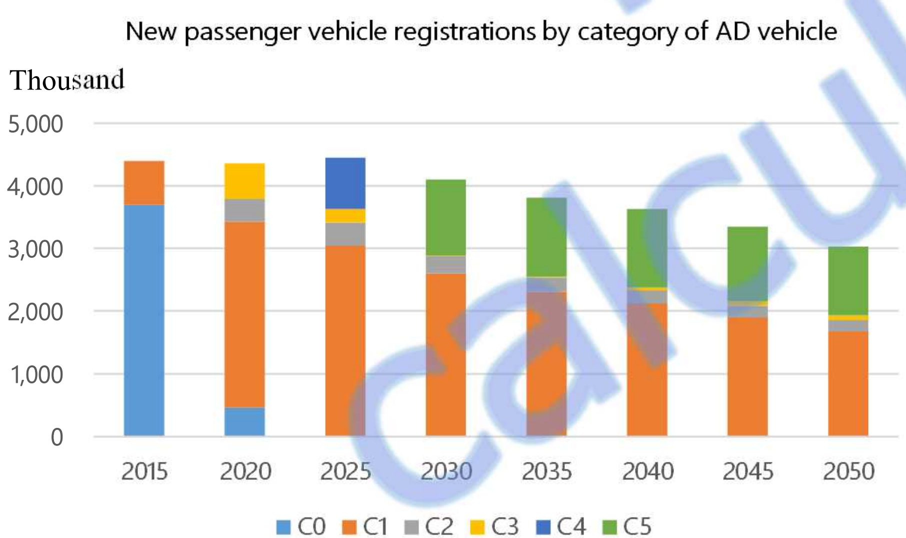
Source: The numbers of vehicles owned in 2015 are provided by the Automobile Inspection & Registration Information Association. The others are estimated values.

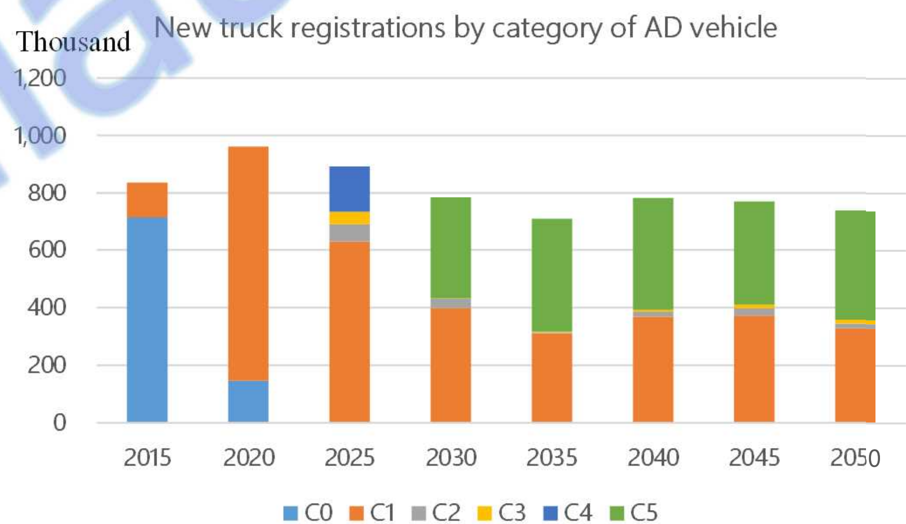
A) Dynamic Model : Base case simulation results (New vehicle registrations)



This estimation shows that new vehicle registrations peak in 2025, starting to decrease after that due to decrease of passenger vehicles resulting from depopulation.

New trucks keep a constant level due to GDP growth.





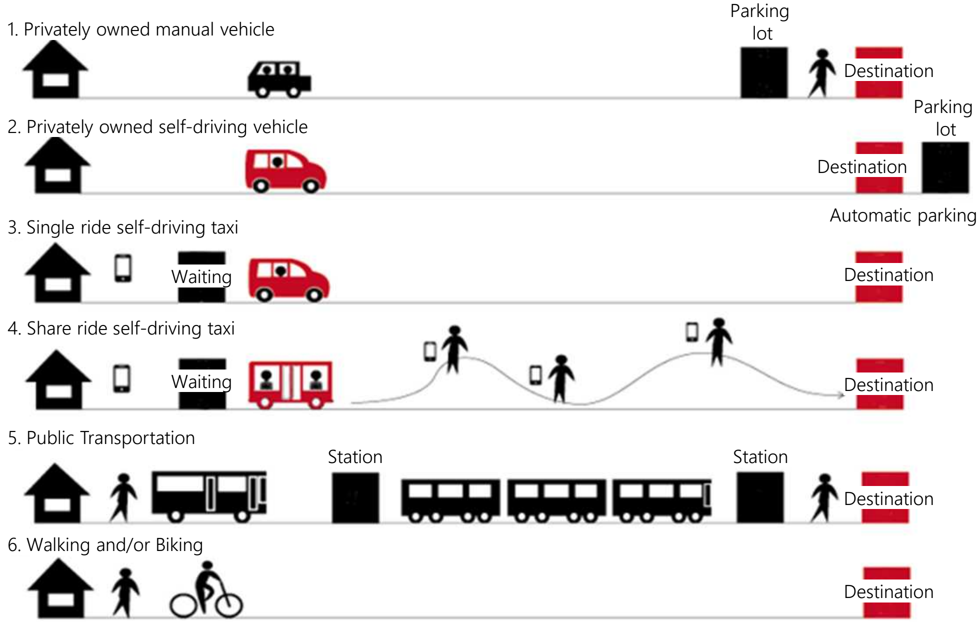
Source: New vehicle registrations are calculated from the numbers of vehicles owned.The numbers of new vehicles by categories of AD vehicles in 2015 are obtained using data provided by MLIT. The others are estimated values.

B) Static Model: Outline

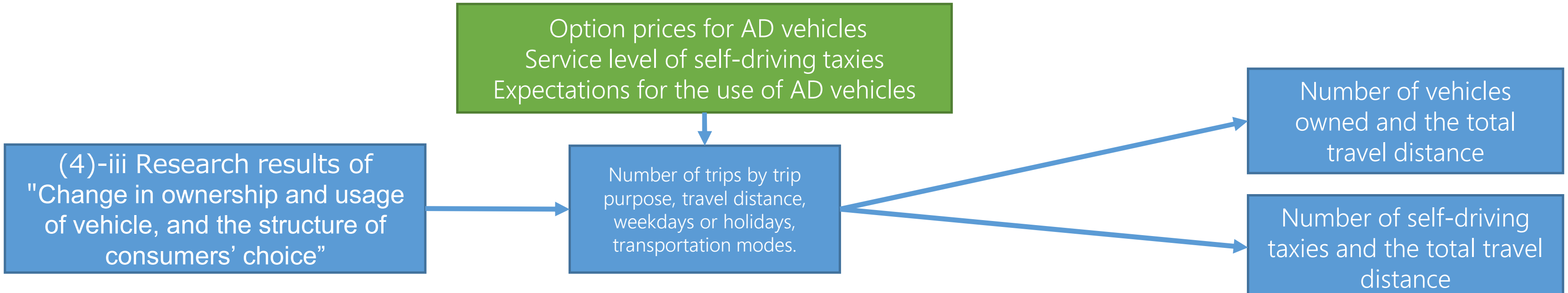
To estimate how car ownership and usage will be in a society where driverless automated vehicles (equivalent to SAE levels 4 or 5) are implemented.
The following six types of transportation modes are assumed to be available to consumer, assuming that car-sharing/ride-sharing by driverless automated taxies is possible,

Transportation Modes
Privately owned manual vehicle
Privately owned self-driving vehicle
Single ride self-driving taxi
Share ride self-driving taxi
Public Transportation
Walking / Biking

Single ride self-driving taxies：Fully automated taxies.
Share ride self-driving taxies：Fully automated taxies. The fare is set lower thanks to riding with other people.
The manual vehicles are equipped with SAE Level 2 driving assistance functions.



To estimate how the followings will change depending on the price of AD vehicles, the level of service of and usage fees for self-driving taxies, and consumers' expectations for using AD vehicles, under the assumption that consumers' trip behavior (purpose, frequency, and travel distance) will remain the same as in 2015.
-Consumers' transportation mode choice,
- Ownership and travel distance of private passenger cars and self-driving taxies.



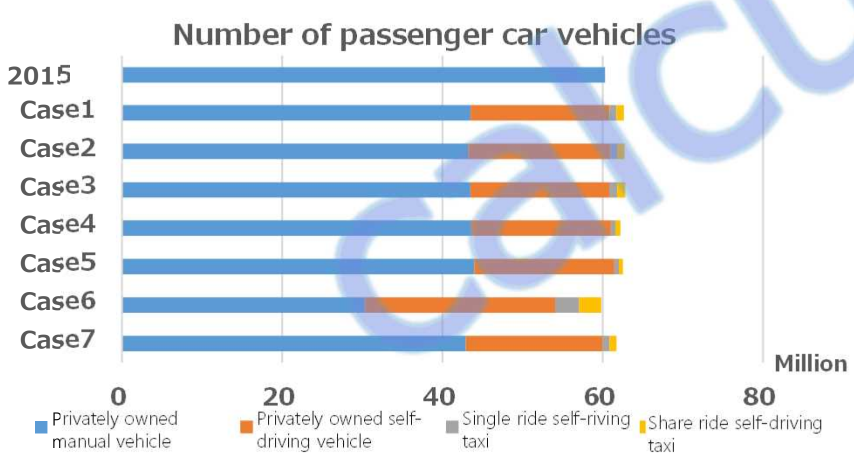
Note: Estimated in this PJ. using microdata of National Urban Traffic Characteristics Survey (FY2010 and FY2015) provided by MLIT.

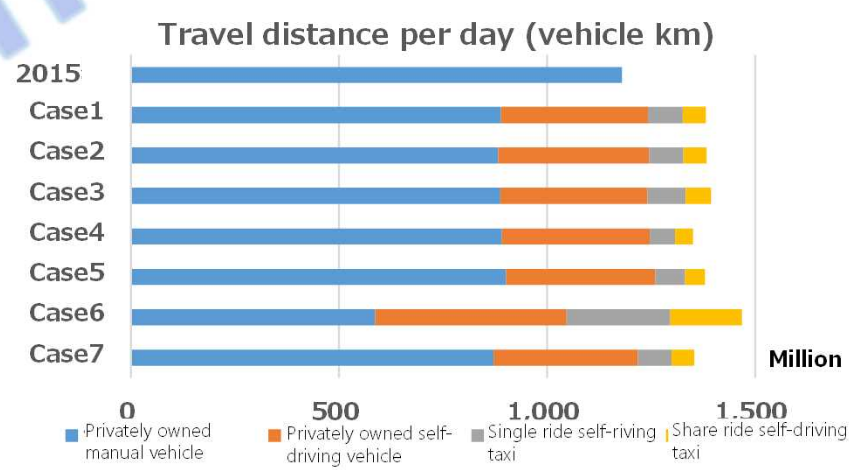
B) Static Model: Simulation results of the number of vehicles owned and travevel distance

The following 7 cases are set using 2015 as the base year and the number of vehicles owned and travel distance are estimated. Expectations of AD vehicles have a greater impact on the number of vehicles owned and travel distance than the option price of AD vehicles or the service level of self-driving taxies.

	Cases	Settings
2015	Base year	Without AD vehicles, single ride self-driving taxies and share ride self-driving taxies
Case 1	Standard Case	AD vehicle option price : 1,000,000 yen; Ffare of self-driving taxies: 25 yen/km; Average time to dispatch for self-driving taxies: 10 minutes; Score of expectation for using AD vehicles: 0.63; Average waiting time for public transportation: 17 minutes
Case 2	Price drop for AD vehicles	AD vehicle option price 1,000,000 yen→ 200,000 yen
Case 3	Price drop for Self-Driving Taxies	Fare of self-driving taxi 25 yen/km → 15 yen/km
Case 4	Price increase for self-driving taxies	Fare of self-driving taxi 25 yen/km → 60 yen/km
Case 5	Increase in waiting time for self-driving taxies	Average time to dispatch for a self-driving taxi: 10 minutes → 20 minutes
Case 6	Increased expectations for use of AD vehicles	Score of expectation for use of AD vehicles 0.63 → 1.00
Case 7	Reduction of waiting time for public transportation	Average waiting time for public transportation 17 min → 6 min

Note: The price for share ride self-driving taxies is set at 77% of that of single ride self-driving taxies





Notes:
1. The number of vehicles owned and travel distance per day in 2015 are provided by the Automobile Inspection & Registration Information Association and MLIT, respectively.
2. Estimated in this PJ. using Microdata of National Urban Traffic Characteristics Survey (FY2010 and FY2015) provided by MLIT.

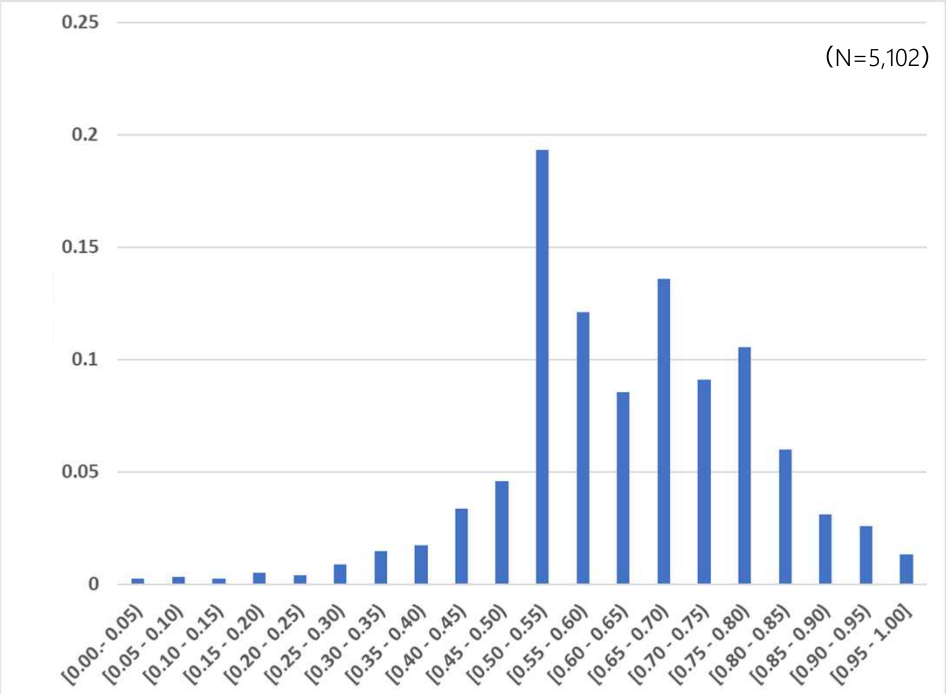
B） Static Model： Consumer's expectations for AD vehicles

Consumer's expectations for fully-automated vehicle in the following table are investigated and scored.

- Definitely No (corresponds to "0")
- Rather No (to "1")
- Neither (to " 2")
- Rather Yes (to "3")
- Definitely Yes (to "4")

1	Resolution or alleviation of traffic congestion
2	Reduction of traffic accidents
3	Environmental load reduction
4	Assistance of transportation of elderly persons, or others
5	Alternatives to public transport in underpopulated areas
6	Increase of opportunity of going out for shopping, amusement, pleasure trip, and others
7	Increase of opportunity of personal interaction with friends, acquaintances, family, and relatives
8	Reduction of private car driver's burden
9	Effective utilization of travel time
10	To allow drivers to call the car from another place
11	Unnecessary to use parking place on–the –go
12	Resolution of shortage of professional driver (for trucks, buses and taxis)
13	Stimulation of economy and enhancement of international competitiveness resulting from new industries

The total of applied scores is divided by 52 (full marks).
The following figure shows the relative frequency distribution of the adjusted total score. The average is 0.63.



Adjusted total score regarding expectation for fully automated vehicle

3 -i Estimation of effectiveness in reducing traffic accidents

<Outline>

- Another research, “Visualize the effects of reducing traffic accidents through Automated Driving and Driving Assistance” sponsored by SIP-adus estimates the reduction of the number of accidents and casualties due to the diffusion of AD vehicles. We estimate the monetary value of reduced traffic accidents.

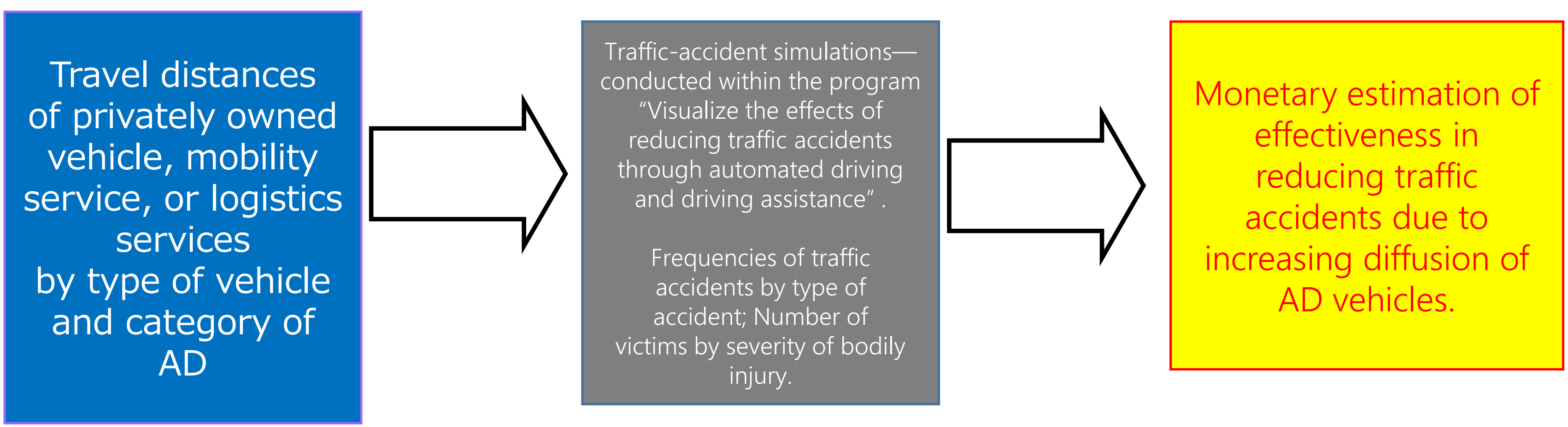
<Method>

- The number of deaths and injuries provided by the above-mentioned research is estimated only for the primary and secondary parties and does not include the third party including fellow passengers. For this reason, the damage caused to fellow passengers is estimated in a complementary manner using Japan Traffic Accident Database (macro data) provided by ITARDA.
- Monetary and non-monetary losses to traffic accident victims and non-monetary losses to traffic accident perpetrators are valued in monetary terms using the number of traffic accident casualties and the economic loss per victim listed on p.25.

Procedural flow for estimating the impact of traffic-accident reduction

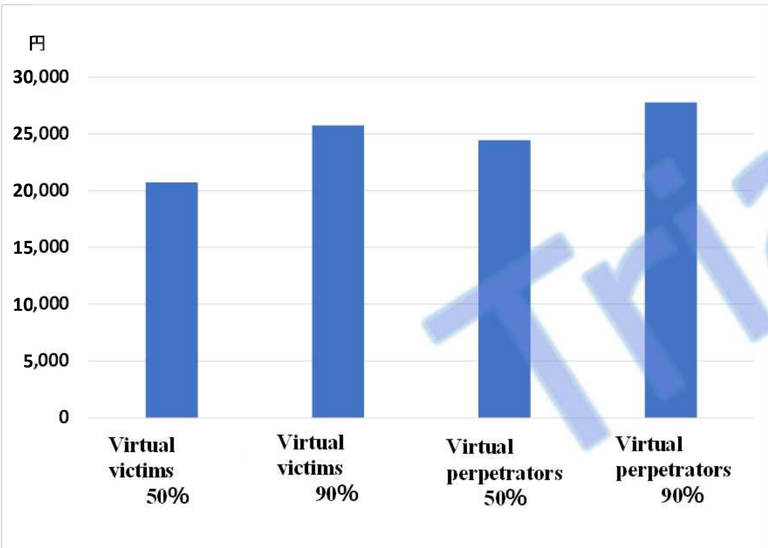
Traffic-accident simulations conducted in above mentioned another research conducted by the Japan Automobile Research Institute predicts changes in the frequency of traffic accidents and the number of traffic-accident victims thanks to diffusion of AD vehicles.

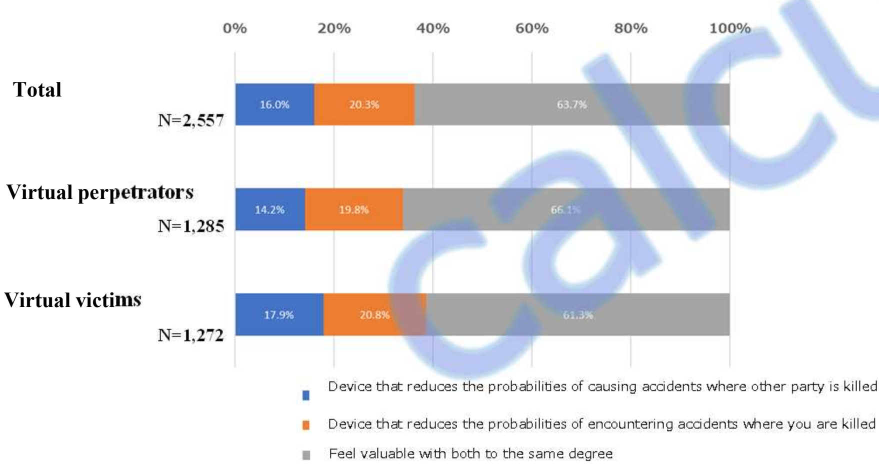
The results are utilized in this research project to estimate the impact of reduced traffic accidents due to increasing diffusion of AD vehicles in monetary terms.



Results of web-survey regarding perpetrator's non-monetary losses

Estimated WTP of annual usage fee (Median)





Two types of web-survey are conducted to make monetary estimation of effectiveness in reducing traffic accidents: survey for virtual perpetrators and one for virtual victims.

Survey for virtual perpetrators : To evaluate the willingness to pay (WTP) of annual usage fee for the device that reduces the probability of causing accident where a driver of other party is killed in an accident between 4-wheel vehicles, by 50 % (90%) under the following assumptions:

1) Probability of causing fatal accident between 4-wheel vehicles in a year is a 1/200,000,
2) Percentage of fault of respondents is 100%.

Survey for virtual victims : To evaluate the willingness to pay (WTP) for the annual usage fee of the device that reduces the probability of encountering accident between 4-wheel vehicles where each respondent is killed, by 50 % (90%) under the following assumptions:

1)Probability of encountering fatal accident between 4-wheel vehicles in a year is a 1/200,000,
2)Percentage of fault of respondents is 0%.

Q : Which device do you feel more valuable under the condition that you and/or your family do not bear any monetary burden at all, device that reduces the probability of causing accident where other party is killed, or one that reduces the probability of encountering accident where you are killed?

Note: The results is obtained using clean-up data after deleting misunderstanding data using a delete pattern.

Economic loss per victim

Economic loss per victim

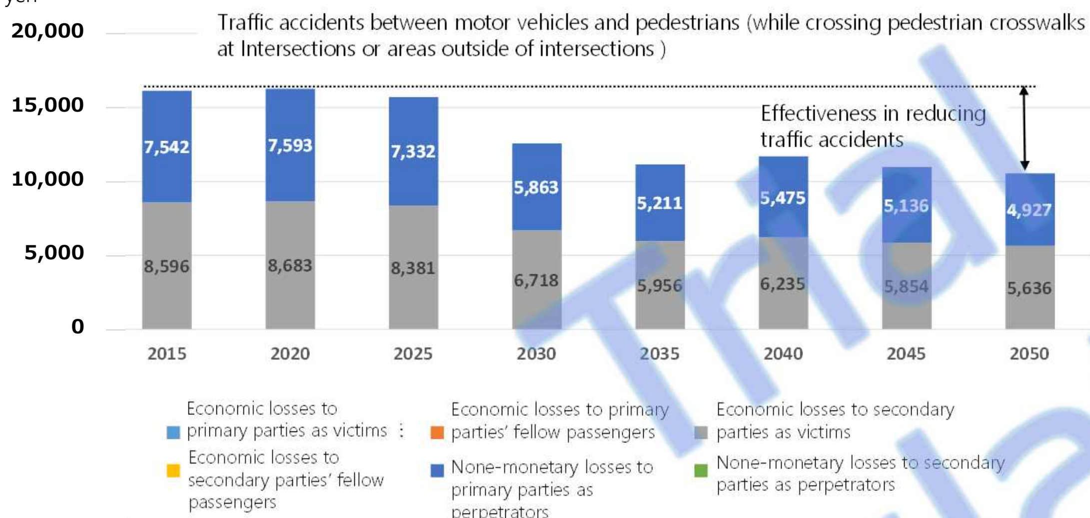
Unit: Ten thousand yen

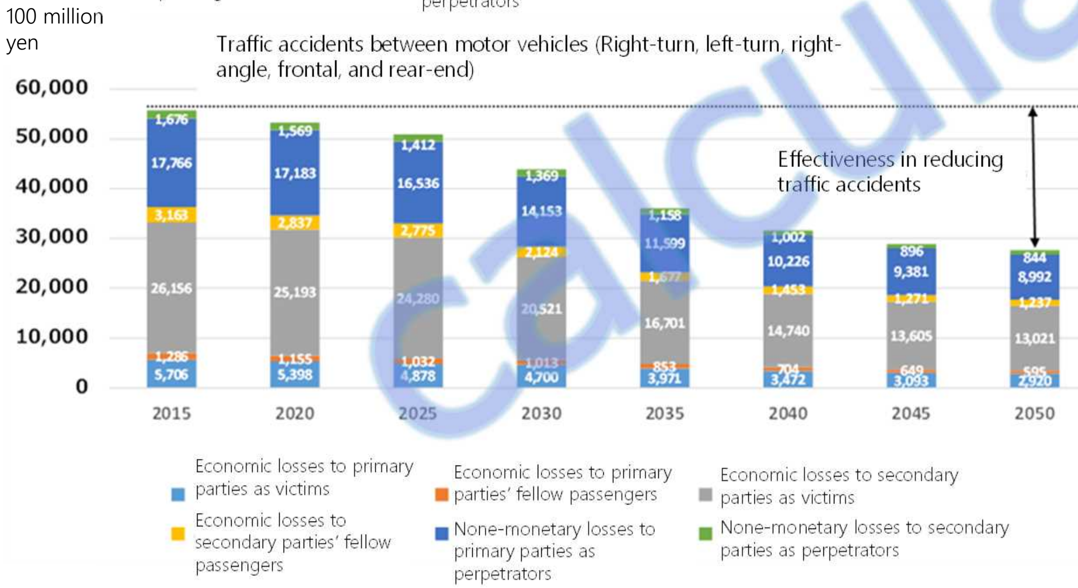
	Victim's economic loss			Perpetrator's non-monetary loss			
				Accident between motor vehicle and pedestrian		Accident between motor vehicles	
Victim's degree of physical injury	Monetary loss	Non-monetary loss	Total loss	Primary party	Secondary party	Primary party	Secondary party
Death	3,292	53,695	56,987	52,191	5,799	43,493	14,498
Serious injury（Injury with residual disability）	906	10,191	11,097	9,906	1,101	8,255	2,752
Slight injury（Injury without residual disability）	153	100	253	97	11	81	27

Note 1: Victim's economic loss is calculated using Table 3.3-1 and Table 5.2-1 in "Research Report on the Economic Analysis of Damage and Losses from Traffic Accidents," March 2017, Cabinet Office Director General for Policy on Cohesive Society (hereafter, Cabinet Office, 2017).
Note 2: The amount of non-monetary loss of the perpetrator is assumed to be 1.08 times that of the victim when the percentage of fault is 1, based on the results of web-survey. The amount of non-monetary loss is assumed to change proportionally to the percentage of fault. The amount of non-monetary loss for the perpetrator in the table is calculated assuming that the ratio of fault of first party to that of secondary party is 9 to 1 in the case of accident between motor vehicle and pedetrian,and 7.5 to 2.5 in the case of accident between motor vehicles, respectively.
Note 3: While the Cabinet Office (2017) categorized the victims' degree of physical injury from the accident into "death," "injuries with residual disability," and "injuries without residual disability," the number of casualties estimated by above-mentioned another research is classified differently as "death," "serious injuries," and "slight injuries. Therefore, we place "injury with residual disability" and "injuries without residual disability" as equivalent to "serious injury" and slight injury", respectively, and conduct the calculations on the next page.

Estimation results of effectiveness in reducing traffic accidents

Economic losses due to road traffic accidents





Note 1: In the above-mentioned another research, the number of traffic accident casualties every five years is calculated assuming the composition ratio of each year's automobile's automatic driving category is eqaul top that estimated in this project., while the traffic distance is fixed at the level of 2015. The numbers in the graph were calculated using the number of casualties estimated by this way and the amount of economic loss per victim on the previous page. The amount of change from 2015 to each year indicates the monetary equivalent of the effect of automation on reducing traffic accidents.

Note 2: The amount of non-monetary loss to the perpetrator is calculated from the total damage of the driver and the fellow passengers of the other vehicle in the accident in the case of an accident between motor vehicles. For example, if the perpetrator is a primary party and the driver and fellow passengers of the secondary party's vehicle are killed, the perpetrator's non-monetary loss would be 434,930 thousand yen*2. On the other hand, in the case of an accident between motor vehicle and pedestrian, a car is considered to be the primary party and a pedestrian is considered to be the secondary party. The non-monetary loss to the driver (the primary party) is calculated from the damage of one pedestrian (the secondary party).

Norte 3: In the above-mentioned another research, vehicles in the C0 category are assumed to be without driving-support devices including collision-damage-reducing brakes.

Note 4: Scope of parties
Primary party: Bus (small-sized and standard-sized), passenger car (standard-sized, small-sized , and mini), truck (standard-sized, small-sized , and mini), special-purpose vehicle, and motorcycle.

Secondary party:Bus (small-sized and standard-sized), passenger car (standard-sized, small-sized , and mini), truck (standard-sized, small-sized , and mini), special-purpose vehicle, motorcycle, bicycle, and pedestrian.

3 - ii . Estimation of reduction of traffic congestion and CO_2 emission

<Outline>

- To estimate the reduction of traffic congestion and CO2 emissions by ADs diffusion

<Methods>

- Same methods established during the SIP-1st phase is applied for estimation at expressways.
- Almost sixty percent of traffic congestion on expressways nationwide are occurring at sag sections.
- ADs are supposed to contribute reduction of traffic congestion and CO2 emission because they promote vehicles' movement with proper headway and speed leading improvements of road traffic capacities.
- Based on the above idea, traffic simulation is used for estimation at two representing sections, a section with three-lane expressway and a section with two-lane expressway. Three ADs diffusion rate, 20%, 50% and 90% are applied.
- For ordinary roads, based on the same idea as above mentioned, existing research results of traffic simulation at the road section with signals (*) are referred.
- Then total amounts of reduction of traffic congestion and CO2 emissions nationwide are calculated.

(*) Study report on international acceptance establishment of CO2 reduction effect evaluation method in transportation sector (Green automotive technology survey and research project in FY2013)

Precondition for estimation

Item	Content
Rate of reduction of traffic congestion and CO2 emission	Results of traffic simulation
Diffusion rate of ADs	20%, 50%, 90%
Road type	Expressways: Intercity expressways Worst 30 sections, sag sections Ordinary roads: Major national highways and high-graded trunk roads
Vehicle type	Passenger vehicles
Performance of ADs (Items giving impacts on traffic congestion and CO2 emission)	Maintaining of speed at sag sections/ Mitigation of lost time at signalized intersections Effect by speed and inter-vehicle time

* Inter-vehicle time: 1.0s, 1.5s and 2.0s
→ 1.5s: Performance same as existing ACC vehicles (equivalent to SAE L1 and L2)
2.0s: Performance with longer inter-vehicle time (equivalent to SAE L3 or above)
1.0s: Minimum inter-vehicle time (as a reference)

* AD's loss time at signalized intersections is 0.2s shorter than ordinary vehicles' one.
* ADs comply with regulated speed.

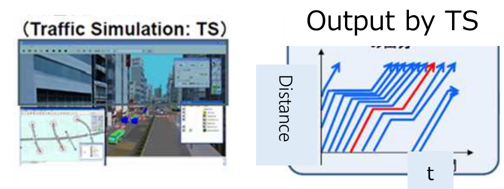
Traffic congestion and CO_2 emission reduction model by ADs diffusion

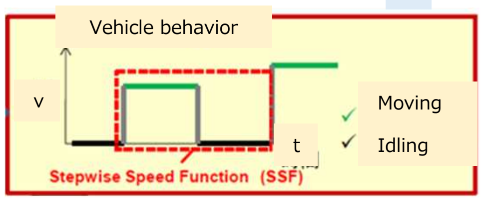
Passenger cars: ADs diffusion model

Vehicle-kms of ADs (passenger cars)

Road geometry, Network
Traffic regulation & control
Traffic demand
Traffic flow, vehicle, driver's characteristics etc.

Traffic simulation in consideration of ADs diffusion
Expressways: Sag bottleneck sections
Other roads: Indispensable freight-road network



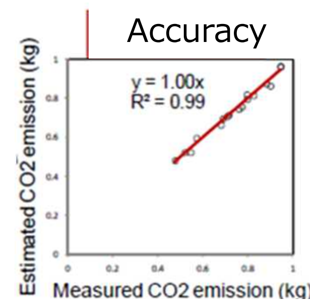


Driving behavior of individual vehicles (average speed, travel time, drive distance, stop time etc.)

Information of vehicle type composition
Information of vehicle emission factors

Estimation of unit reduction of traffic congestion along with the diffusion of ADs
(Expressways, Other roads)

Estimation of unit reduction of CO_2 emission along with the diffusion of ADs
(Expressways, Other roads)



CO_2 emission

Data for the extension of estimation

Data for the extension of estimation

Estimation of nationwide traffic congestion reduction
(Expressways, Other roads)

Estimation of nationwide CO_2 emission reduction
(Expressways, Other roads)

* Estimated by the CO_2 emission model developed by JARI

(Source) Study report on international acceptance establishment of CO_2 reduction effect evaluation method in transportation sector (Green automotive technology survey and research project in FY2013)

(Nationwide estimation: Expressways) Traffic congestion reduction and CO2 emission reduction

- The below graphs show the reduction rates for traffic congestion in the worst 30 sections in case of inter-vehicle time of 1.5s.

  (C1/ C2 in this study, equivalent to SAE L1/ L2)

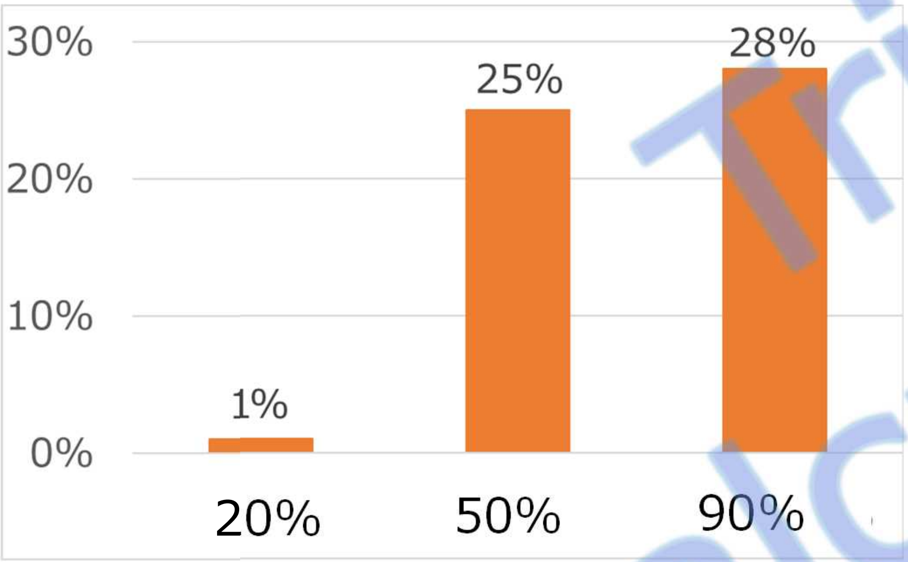


Fig. Reduction rate of loss time

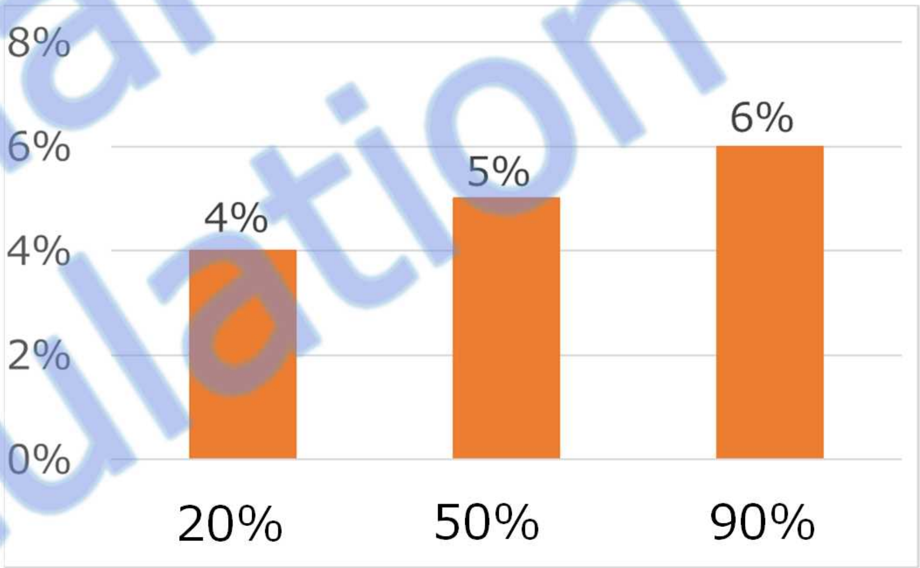


Fig. Reduction rate of CO2 emission

- “20%” and “50%” are corresponding to the diffusion rate at 2020 and 2025 calculated by the dynamic diffusion simulation.

(Nationwide estimation: Ordinary roads) Traffic congestion reduction and CO_2 emission reduction

- The below graphs show the results in case of inter-vehicle time of 1.5s.

  (C3 in this report, equivalent to SAE L1/ L2)
- Stable traffic flow, prevention of capacity drop by less variety of departure loss at signalized intersections and less factors causing traffic disturbance are expected because ADs run at stable speed on ordinary roads.

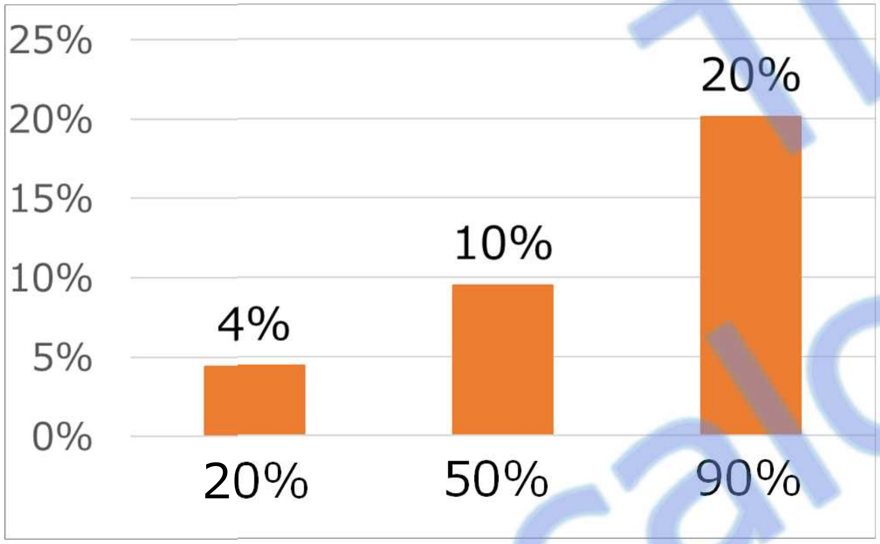


Fig. Reduction rate of loss time

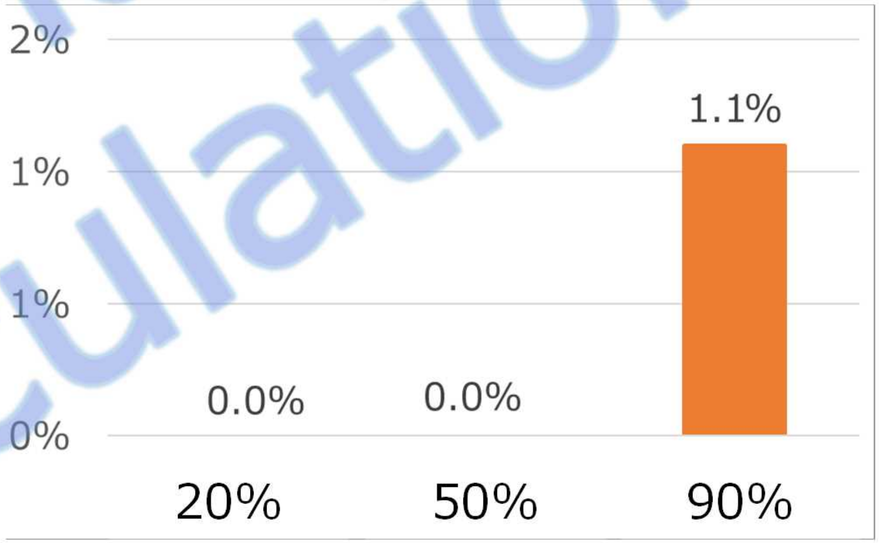


Fig. Reduction rate of CO2 emission

4 - i Ensuring mobility for vulnerable road users and in depopulated areas and other locations with poor access to transport

<Outline>

- To summarize possibilities of new business and life brought by AD technologies, particularly on remote areas

<Methods>

- To implement interview surveys for staff of municipal governments in remote areas on use cases of AD technologies

Use cases of ADs found by interview surveys

- Alternative of driving services
  - To substitute ADs for current driving services
    - Labor-saving (reduction of drivers' work load)
    - Fully unmanned

- Expansion of administrative services
  - To improve administrative services level by AD technologies
    - Improvement of service frequency and expansion of service area
    - Improvement of service quality

  → Enhancement of service (Assist, Medical inspection, Escort, On-site check, Disaster response)
    - Improved service for supported people and fellow passengers
    - Improvement of attention during on-site checks and disaster responses

- Creation of new administration services
  - Realization of new services

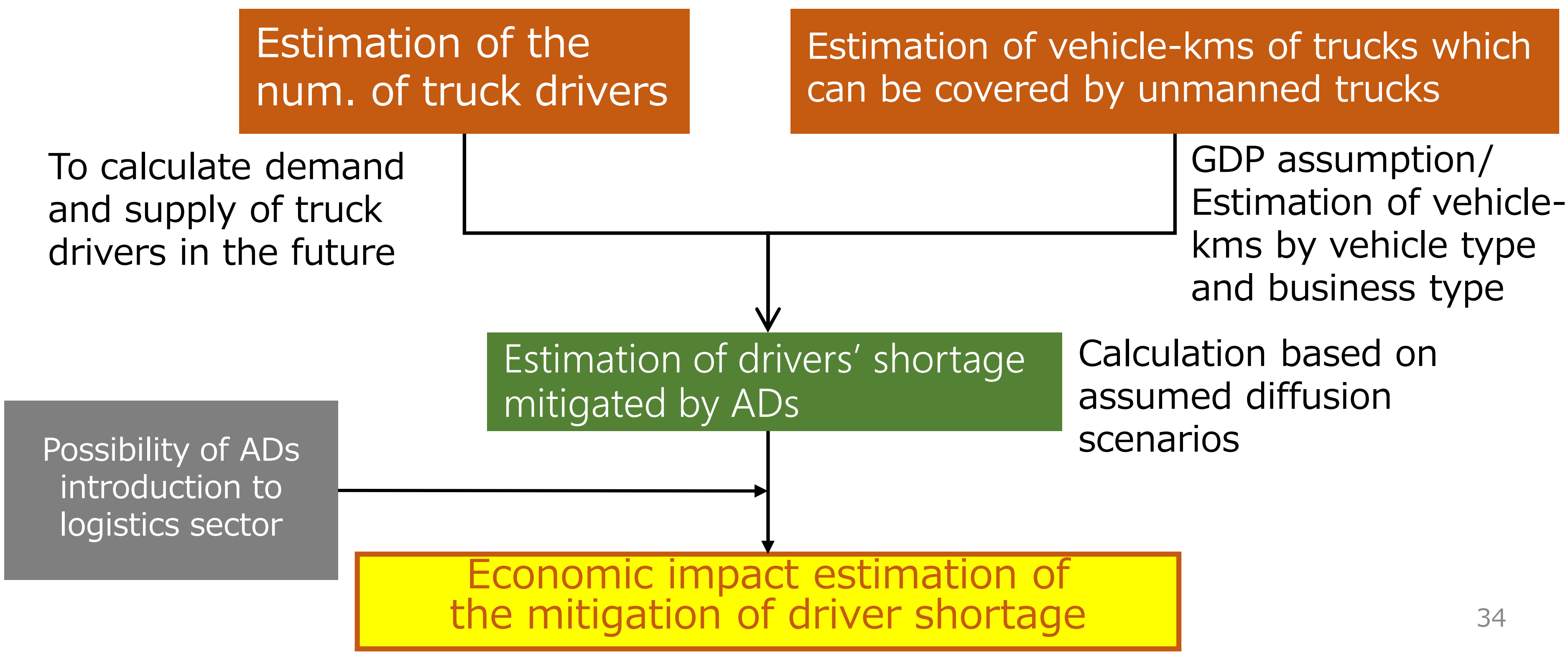
  → Automatic diagnosis identification (On-site check, Disaster response)
    - Identification of diagnosis, Emergency treatment

4- ii Reduction of costs and resolution of driver shortage in logistics and transport services

<Outline>

- To estimate how ADs introduction will contribute as a solution against the on-going shortage of truck drivers

<Methods>



Assumed diffusion scenario of ADs

The following scenarios are assumed based on the Public-Private ITS Initiative/Roadmaps.
A model estimating the number of driver shortage mitigation and its economic impact is established in accordance with GDP assumption and diffusion scenarios.

Scenario		2025	2035	2040
1	Fully automated driving of trucks on some specific sections of expressways	Commencement	〇 Achievement	
2	Fully automated driving of trucks on expressways with 4 lanes and more		〇	
3	Unmanned autonomous driving delivery service in specific areas (remote areas)	Commencement	〇 Achievement	
4	Unmanned autonomous driving delivery service in specific areas (all areas except urban and sub-urban areas)		〇	〇
5	Fully automated driving of trucks on major ordinary highways			〇

Trial calculation of replacement of truck drivers by ADs

- Under the some assumption including the ADs diffusion scenario No.2 and No.4, the gap between demand and supply of truck drivers might be improved about 79% in 2035.

- In case goods trucks on expressways replaced by ADs, about 63% of economic losses, which would be caused by truck driver shortage might be avoided in 2035.

(4)-iii. Change in ownership, usage of vehicle, and consumers’ behavior in mode choice

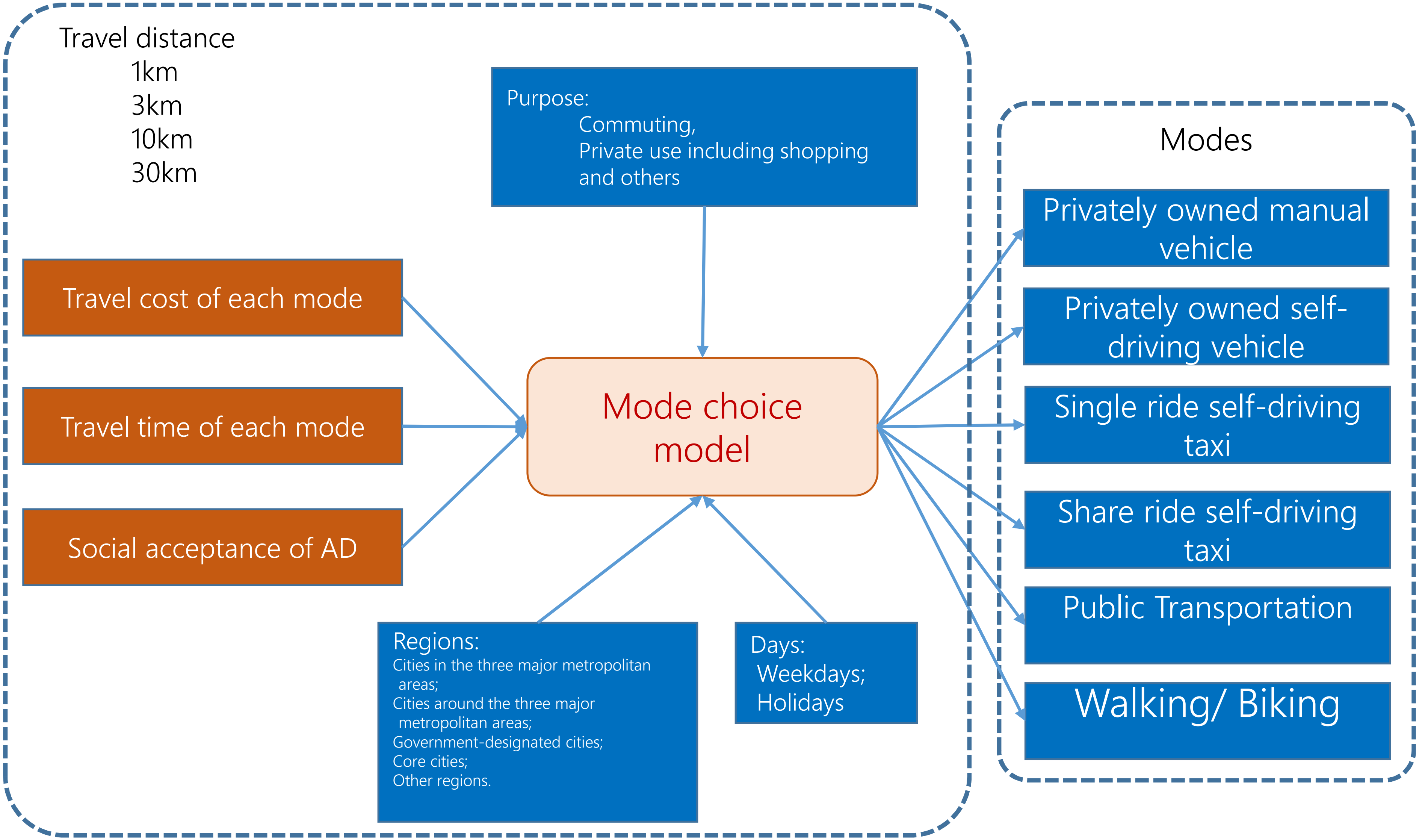
<Outline>

- To estimate how consumers’ choice regarding the ownership and usage of vehicle, and mobility will change by introduction / diffusion of AD vehicles and MaaS.

<Method>

- To construct a transport mode choice model from the results of web questionnaire survey.
- We estimate how consumers’ behavior in the choice of transport mode will change depending on the price of AD vehicles, the level of service of self-driving taxies, and the level of expectation for using AD vehicles. However, we assume that consumers' travel purpose, travel frequency, and travel distance will remain the same as in 2015.

Mode choice model



Note: Estimated in this PJ. using Microdata of National Urban Traffic Characteristics Survey (FY2015) provided by MLIT.

Modal share after the spread of fully automated vehicles

Using 2015 as the base year, we set the following 7 cases and estimated the share of each mode.
Expectations of AD vehicles will have a greater impact on transportation mode choices than the option price of AD vehicles or the level of service of self-driving taxies.

	Cases	Settings
2015	Base year	Without AD vehicles, single ride self-driving taxies and share ride self-driving taxies
Case 1	Standard Case	AD vehicle option price : 1,000,000 yen; Ffare of self-driving taxies: 25 yen/km; Average time to dispatch for self-driving taxies: 10 minutes; Score of expectation for using AD vehicles: 0.63; Average waiting time for public transportation: 17 minutes
Case 2	Price drop for AD vehicles	AD vehicle option price 1,000,000 yen→ 200,000 yen
Case 3	Price drop for Self-Driving Taxies	Fare of self-driving taxi 25 yen/km → 15 yen/km
Case 4	Price increase for self-driving taxies	Fare of self-driving taxi 25 yen/km → 60 yen/km
Case 5	Increase in waiting time for self-driving taxies	Average time to dispatch for a self-driving taxi: 10 minutes → 20 minutes
Case 6	Increased expectations for use of AD vehicles	Score of expectation for use of AD vehicles 0.63 → 1.00
Case 7	Reduction of waiting time for public transportation	Average waiting time for public transportation 17 min → 6 min

Note) The price for share ride self-driving taxies is set at 77% of that of single ride self-driving taxies.

Note: Estimated in this PJ. using Microdata of National Urban Traffic Characteristics Survey (FY2015) provided by MLIT.

5. Effect on industry and society
i Impact on the automobile industry due to changes in the automobile ownership structure and others

<Outline>

- Research on the impacts on the automobile industry and the whole Japanese industry by the changes below:
  - Changes in automobile ownership due to the diffusion of AD vehicles, car sharing/ride sharing and others.
  - Changes in automobile components due to the shift to automated driving and electrification.

<Method>

- To estimates of changes in components as automobiles become automated and electrified.

- Impacts on production value and employment in the automobile industry and the whole Japanese industry are estimated using the inter-industry relations table. The inter-industry relations table is assumed to remain unchanged except for changes in components due to the shift to automated and electric vehicles.

Classification

To classify vehicle base on category of AD and type of electrification

Passenger vehicles produced in the year of 2016 (I-O table year) are assumed to be without driving support devices including collision-damage-reducing brakes, for simplification. Parts costs are estimated only for the automated categories C2 and above,

Parts costs are estimated for each electrification (HV, PHV, and EV).

■Categories of AD vehicles considered in this study

Category	Highways	General roads	Compatible technologies
C0*	SAE Lv. 1 or less	SAE Lv. 1 or less	Level under C1
C1*	SAE Lv. 1 Driver assistance	SAE Lv. 1	Equipped with all the following four devices ・Collision-damage-reducing brakes ・Acceleration limiters for accidental accelerations (due to driver error) ・Lane-departure warning system ・Car distance warning system
C2	SAE Lv. 2 Partial automation	SAE Lv. 1	In addition to C1: ・On highways, lane keeping systems (LKAS) + adaptive cruise control (ACC) ・Automatic lane changing on highway

Category	Highways	General roads	Compatible technologies
C3	SAE Lv. 3 Conditional automation	SAE Lv. 2	In addition to C2: ・Lv. 3 on highways ・Lv. 2 on general roads
C4	SAE Lv. 4 High automation	SAE Lv. 3 on major arteries and thoroughfares	In addition to C3: ・Lv. 4 on highways ・Lv. 3 on major general roads ・On general roads, take-over requests (TORs) for driving operations will be issued in response to system demand
C5	SAE Lv. 4 High automation	SAE Lv.4 on major arteries and thoroughfares	In addition to C4: ・Lv. 4 on major general roads ・Take-over requests (TORs) will not be issued

*Out of scope of parts cost estimation.

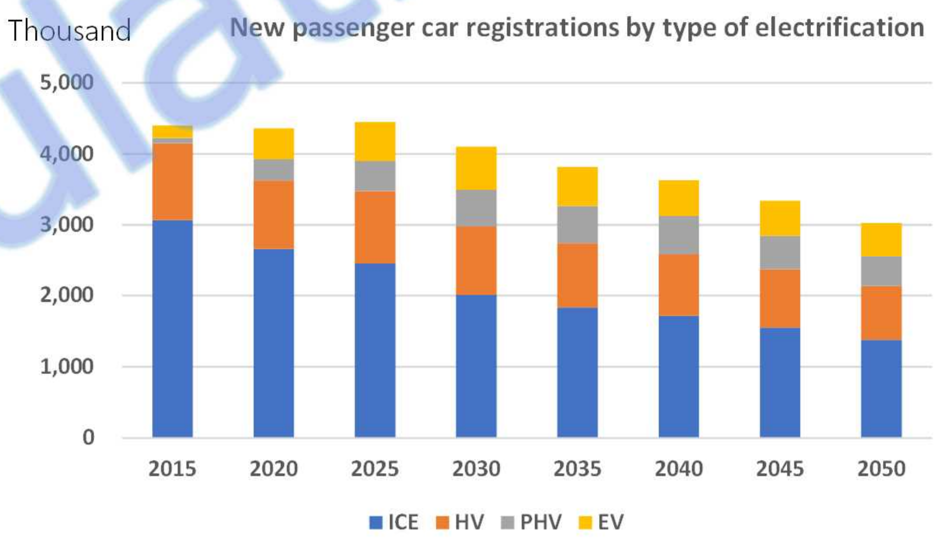
■Electrification considered in this study

Type	Description
ICE	Internal combustion engine vehicle
HV	Hybrid vehicle
PHV	Plug-in hybrid vehicles
EV	Electric vehicles

New vehicle registrations: Simulation results of dynamic diffusion simulation model (GDP medium-variant Case)

- The number of new vehicle registrations by both category of AD and type of electrification estimated in the dynamic model of diffusion simulation is as follows:
  - The number of passenger car registrations decreases after 2025 due to the decrease of population,
  - No big change in the ratio of each category of AD after 2030.

Source: The number of C1 in 2015 is set based on the actual value obtained from "Survey on Prevalence of ASV Technology (as of Dec 26, 2018) " issued by the MLIT. The others are estimated values.

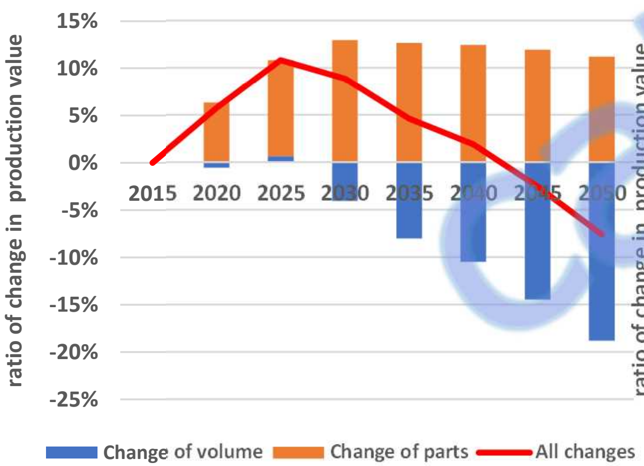


Source: The ratios are set based on the report on diffusion strategy for next-generation vehicles prepared by Japanese Ministry of the Environment, May 2009

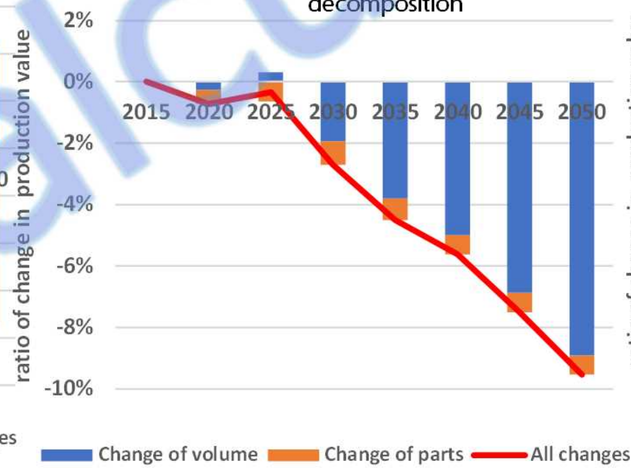
Estimated Impacts

- To evaluated the impacts of changes in the number of passenger cars produced and shift to automated driving and electrification on the production value of the passenger car sector, automobile parts / accessories sector, and all industries, using the estimated production costs and prices of each category of AD.
- The production value of the passenger car sector will increase with the progress of autonomous driving until 2025. It will decrease with the decrease in production volume after 2025.
- Both the production value in the automobile parts and accessories sector will decrease. It is thanks to the decrease in both the number of passenger cars produced and demand of the internal combustion engine.
- In all industries, the production will increase due to the increased demand for autonomous driving parts, but it will eventually become negative compared to 2015 due to the decrease in production volume.

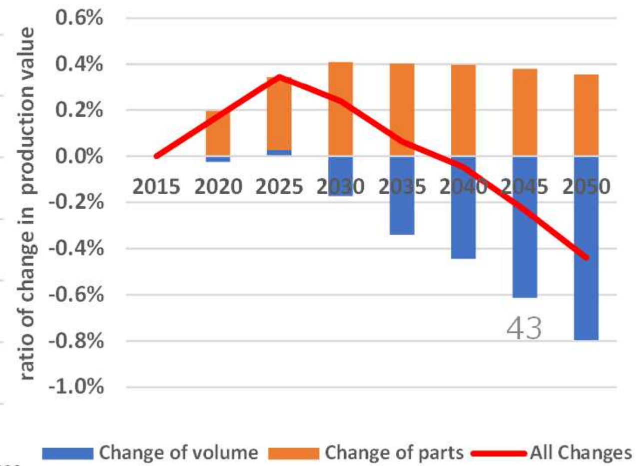
The production value change of the passenger car sector compared with the level of 2015 and its decomposition



The production value change in the automobile parts and accessories sector compared with the level of 2015 and its decomposition



The production value change in all industries compared with the level of 2015 and its decomposition



Source: Estimated using 2016 Updated Input-output Table provided by METI, and others

5. Effect on industry and society
ii Contribution to growth of total factor productivity of Japanese economy

< Outline >

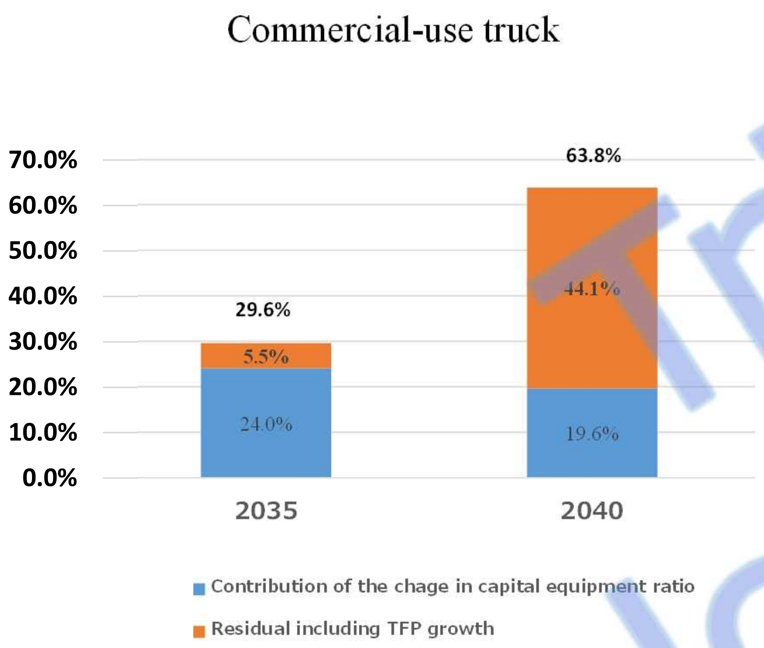
- The results of the estimated resolution of the truck driver shortage calculated in "(4)-ii Reduction of costs and resolution of driver shortage in logistics and transport services" are converted into the effect of increases in labor productivity and total factor productivity.

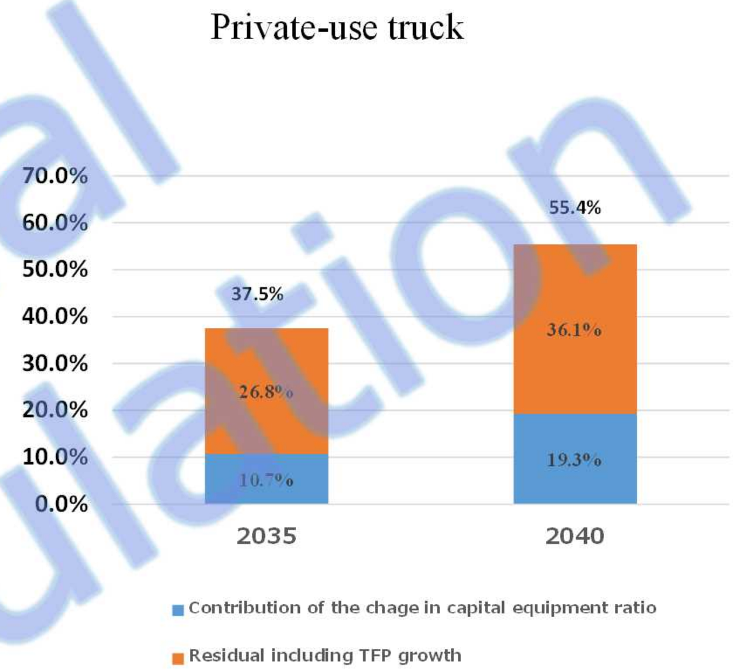
Calculation methodology

Labor productivity growth
＝TFP growth＋Capital equipment ratio growth＊（1 − Labor share）

Item	Calculation method	Notes
Labor productivity	Total output/number of workers, Total output: vehicle kilometer of travelled, Number of workers：number of truck drivers	The values calculated in "(4)-ii Reduction of costs and resolution of driver shortage in logistics and transport services are used for the total output and the number of workers
Capital Equipment ratio	Gross capital stock/Number of workers Gross capital stock = Number of trucks owned × (Body price + Option price of AD vehicle category (higher than C1）) The number of trucks is calculated in a dynamic model simulation.	Body price of new car Standard-sized：6,000 JPY Small-sized：4,000 JPY Mini：1,500 JPY Option price of AD vehicle category (higher than C1）for trucks is assumed to be three times as much as that for passenger cars
Labor share	Calculated from Extended 2016 I-O Table provided by METI. Labor share: 0.713（Compensation of employees / Gross value added）	

Productivity improvement in the logistics industry through automation





Note: Growth rate compared to 2015

6. Research activities with international cooperation

- Japanese-German cooperation
  - The joint research was commenced based on the Joint Declaration of Intent signed on Jan. 12, 2017 by the Cabinet Office of the Japanese government (CAO) and the German Federal Ministry of Education and Research (BMBF)
  - The first joint meeting was held on Oct. 7 and 8, 2019 at German Aerospace Center, Berlin.
  - Research contents of both sides were presented, then mutual interesting research areas were shown and finally fields of information sharing and joint research were discussed.
  - The second and third joint meetings were held on Jun. 16 and 30, 2020 via online for information sharing and discussion on mutual interesting research area.
  - The online symposium was held on Nov. 12, 2020.
  - The activity progress was reported to CAO and BMBF at the Steering Committee meeting on May 29, 2020 and at the Expert Workshop on Nov. 25, 2020.

7. Convening of Advisory Committee

- The meetings of the advisory committee were held six times.
  (7th Mar 2019, 26th Jun 2019, 1st Oct 2019, 3rd Feb 2020, 28th Oct 2020, 10th May 2021)

Members of the Advisory Committee on the Social Impact of Automated Driving Systems

Name	Affiliation	Speciality
Masato Itohisa	Associate Professor, Faculty of Social Science, Hosei University	Technology management
Takeyoshi Imai	Professor, Graduate School of Law, Hosei University	Criminal law
Keisuke Uehara	Associate Professor, Faculty Environment and Information Studies, Keio University	Iinformation technology
○ **Takashi Oguchi**	Professor and Director, Advanced Mobility Research Center, Institute of Industrial Science, The University of Tokyo	Traffic control engineering
Shusuke Kakiuchi	Professor, Faculty of Law, Graduate Schools for Law and Politics, The University of Tokyo	Civil procedure law
Masanobu Kii	Professor, Faculty of Engineering and Design, Kagawa University	Urban and transportation planning
Yuto Kitamura	Associate Professor, Graduate School of Education, The University of Tokyo	Education
Ryo Kurachi	Specially Appointed Associate Professor, Center for Embedded Computing Systems, Graduate School of Informatics, Nagoya University	Cybersecurity
Osamu Sakura	Professor, Interfaculty Initiative in Information Studies, Graduate School of Interdisciplinary Information Studies, The University of Tokyo	Science, Technology and Society
Yasuhiro Shiomi	Associate Professor, Department of Civil and Environmental Engineering, College of Science and Engineering, Ritsumeikan University	Traffic engineering
Naoki Suganuma	Professor, Automated Vehicle Research Unit, Future Society Creation Research Core, Institute for Frontier Science Initiative, Kanazawa University	Robotics engineering
Satoshi Taguchi	Professor, Faculty of Commerce and Director, Institute for Technology, Enterprise and Competitiveness, Doshisha University	Behavioral economics
Akihiro Nakamura	Professor, Faculty of Economics, Chuo University	Public economics
Pongsathorn Raksincharoensak	Professor, Department of Mechanical Systems Engineering, Tokyo University of Agriculture and Technology	Machine dynamics and control
Hiroaki Miyoshi	Professor, Faculty of Policy Studies, Institute for Technology, Enterprise and Competitiveness, Doshisha University	Technology and public policy
Akinori Morimoto	Professor, Department of Civil and Environmental Engineering, Faculty of Science and Engineering, Waseda University	Urban planning
Goro Yamazaki	Associate Professor, Center for the Study of Co Design, Osaka University	Cultural anthropology