CURRENT SITUATIONS ON HIGH CAPACITY TRANSPORT AND TRUCK PLATOONING IN JAPAN

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Abstract

This paper unveils the current situations and issues on high capacity vehicles(HCVs) and truck platooning in Japan and summarizes suggestions for future logistics measures in Japan through a comparison between Japan and Europe. As for HCV, Japan is similar to Germany in HCV introduction, which did not relax gross weight but conditionally relaxed total length. In Europe, further relaxation of regulations for both the full length and total weight based on performance-based standards(PBS) was found. As for truck platooning, the inter-level functions are almost the same between Europe and Japan regarding platooning automation level, but Europe is ahead in the effort for international standardization among multinational truck manufacturers and participation of major logistics companies in tests. The suggestions for future logistics measures in Japan include expansion of parking facilities, expansion of traveling sections, deregulation of gross weight for HCVs, diversification of HCV types, promotion of joint transportation, and infrastructure development.

Keywords: Freight Transport, High Capacity Vehicle, Truck Platooning.

1. Introduction

Recently, due to increasing freight transportation demands and a serious lack of drivers, efforts are being made around the world to improve the labor-saving and efficiency in freight transportation by using high capacity vehicles(HCVs)(ITF, 2019). HCV is a heavy-duty truck on which restrictions on the full length and total weight are greatly reduced. Although Longer and Heavier Vehicle, Mega Truck and Giga Liner are used as equivalent terms for HCV, we will use the term HCV in this study, because it is frequently used in the academic field.

Many European countries, the U.S., Australia and other countries introduce HCVs in earnest after conducting field operational tests and deregulating the full length and total weight of trucks(Steer et al., 2013). With regard to truck platooning, major truck manufacturers in Europe and the U.S. have carried out technological developments for a manned following vehicle platooning system(Janssen et al., 2015; ACEA, 2017). In Europe, large-scale field operational tests on public roads are conducted/planned, getting logistics companies involved in the Netherlands, Germany and the UK.

In Japan, standards of vehicle length for traffic permission of special vehicles was relaxed so that the introduction of a 25-meter vehicle (including double-trailer trucks) was officially permitted(MLIT, 2019a). With regard to truck platooning, field operational tests on expressways have been conducted with manned following vehicles since fiscal year(FY) 2017(Truck Platooning Initiative, 2020). For introduction of unmanned following truck platooning, infrastructure improvement, laws and regulations, and its commercialization have been discussed(MIRI, 2019).

In this study, we investigated the progress of the introduction and the issues in the deployment of double-trailer trucks and platooning in Japan. We gathered the most current information on field operational tests that conducted policymakers, research institutions, logistics companies and truck manufacturers, and technological development trends to summarize the suggestions for logistics policies.

2. Introduction of high capacity vehicles in Japan

2.1 Outline of field operational test and official introduction

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) conducted a field operational test of high capacity vehicles from FY2016 to FY2018 to study the possible relaxation of the special vehicle passage permit standard (maximum vehicle length) from 21 meters to 25 meters, by focusing on two types of trailer combinations: (1) a rigid truck with a trailer and (2) a tractor unit with semi-trailers: B-double(MLIT, 2019a). The field operational test involved four logistics companies invited through public invitation. The project took place on the Shin-Tomei Expressway, which these logistics companies mainly used for their long-distance cargo transportation (up to 500 km). The longer and heavier HCVs were specially permitted for passage for this project to investigate their behavior on the road as well as potential advantages in labor saving, reduction of environmental impact, and driving safety.

The test results compiled and published by MLIT in 2018 demonstrated that the introduction of HCVs could produce various advantages with fewer traffic safety problems(MLIT, 2019a). More specifically, compared to standard freight trucks, HCVs can reduce the number of drivers required for transportation by around 50% (labor saving) and CO_2 emissions by

around 40% (reduction of environmental impact). On the other hand, the report eliminated the concerns over driving safety. HCVs on curved sections or changing lanes on expressways showed few cases of dangerous behavior, such as sudden braking, rolling, and wobbling. When turning left or right at intersections on general roads, HCVs also had little impact on the surrounding vehicles.

Based on the above results, in January 2019, the special vehicle passage permit standard (maximum vehicle length) was officially relaxed to allow up to 25 meters for a van-type rigid truck with a trailer(MLIT, 2019a). The introduction of HCVs, however, is required to satisfy the conditions listed in Table 1 in consideration of road maintenance and traffic safety. In the meantime, the MLIT report also proposed the actions necessary to expand the use of HCVs in the future, such as the development of parking spaces on expressway service areas(SAs) and parking areas(PAs), where HCVs have priority use, and the expansion of expressway routes that allow passage of HCVs.

Table 2 shows the numbers of business operators and their HCVs with a vehicle length of about 25 meters. As shown in the table, the numbers are steadily increasing year by year.

Table 1 - Main requirements in introducing HCVs

Requirement	Description
Vehicle	A van-type rigid truck with a trailer, with a total length of 25 meters or less
Equipment	Sixteen technical requirements concerning vehicle safety, including anti-lock braking, lane departure warning, and ETC2.0*
Load	No transportation of hazardous articles, large amount of liquid, animals, etc.
Traveling	(1) Prohibition of overtaking, (2) prohibition of tandem driving (3) passage of alternative routes, (4) emergency stop display in case of problems, (5) activation of operation-supporting ETC2.0 on-board unit, and (6) carrying of required documents
Traveling route	Designated sections of expressways and the route to enter and return from that section for HCVs

(Source: MLIT, 2019a)

* ETC2.0: A single platform system that provides multiple ITS spot services in addition to an electronic toll collection (ETC) system, including various driving support information.

Table 2 - Number of HCVs introduction

FY	Number of companies	Number of vehicles	Period
2017	2	3	Field operational test
2018	3	5	
2019	6	14	After official deregulation
2020	7	33	

(Source: Prepared by authors based on MLIT, 2019a)

2.2 Efforts to expand the deployment of HCVs

Both private and public sectors are trying to expand the use of HCVs(MLIT, 2019a). In March 2019, four home-delivery service companies (Yamato Transport, Seino Transportation, Nippon Express, and Japan Post) jointly started the coordinated highway transportation of cargoes between Kanto and Kansai areas by using HCVs. This joint highway transportation uses the HCVs officially approved (a van-type rigid truck with a trailer). The trailers (towed, following vehicles) provided by Yamato Transport are connected to tractors (towing, leading vehicles) provided by the other three companies at logistics facilities of Yamato Transport.

In August 2019, in addition to part of Shin-Tomei Expressway where the test was originally conducted, the MLIT expanded the HCV passage routes to parts of other 13 expressways by relaxing the special vehicle passage permit standard (maximum vehicle length) up to 25 meters. The expansion of the road network for HCVs across the country is expected to streamline the transportation of cargoes. In FY2019, the MLIT and the Ministry of the Environment jointly started a project to support the introduction of HCVs by utilizing the framework of subsidies for CO_2 emissions mitigation measures. In this project, the government subsidizes part of the expenses that private companies incur in introducing HCVs (a van-type vehicle with a length exceeding 19 meters, either a rigid truck with a trailer or a tractor with semi-trailers).

3. Truck platooning trials in Japan

3.1 Technical development for truck platooning

In Japan, the development of vehicle technology necessary for truck platooning had been carried out under the Development of Energy-Saving ITS Technologies Project (2008-2012) of the New Energy and Industrial Technology Development Organization (NEDO, 2013; Tsugawa, 2013). In this project, the cooperative adaptive cruise control (CACC) system that controls the trucks in a longitudinal direction and the lane keeping assistant (LKA) system that controls in a lateral direction were developed. By applying these technologies, in normal time, the following vehicles can travel while recognizing the white line on the road and controlling the steering. When it is difficult to recognize the white line (e.g., merging/branching sections etc.), the following vehicles can still follow the leading vehicle. The truck can also automatically change lane and apply the emergency brake when it detects an obstacle. The experimental project was participated in by four Japanese freight vehicle manufacturers (Isuzu Motors, Hino Motors, Mitsubishi Fuso, and UD Trucks). With these technologies, the test successfully realized platooning of large freight trucks at a speed of 80 km/h with an inter-vehicle distance of 4 meters.

3.2 Current status of field operational test of truck platooning

Based on the successful technical development above, the MLIT and the Ministry of Economy, Trade and Industry (METI) had conducted a field operational test of truck platooning on expressways since FY2017(Toyota Tsusho, 2018). Aiming to realize truck platooning with unmanned following vehicles at the end, the project had verified the vehicle technologies one by one under the various road conditions. From FY2017 to FY2018, the tests verified the technologies required for truck platooning with manned following vehicles, such as automatic control in a longitudinal direction (CACC, level 1) and the same in a longitudinal and lateral direction (CACC + LKA, level 2). The tests were conducted on multiple expressway routes. The inter-vehicle time between trucks in a platoon was set to 1.6 seconds (inter-vehicle distance: 30-35 meters).

Since FY2018, the tests verified the technology required for truck platooning with unmanned following vehicles(Truck Platooning Initiative, 2020). In platooning with unmanned following vehicles, the inter-vehicle distance was reduced compared to the one in platooning with manned following vehicles (inter-vehicle time: 0.5 seconds), because of the elimination of the following driver's stress or fear caused by the short inter-vehicle distance from the leading vehicle. In addition, platooning with unmanned following vehicles also introduced and verified a minimal risk maneuver (MRM) technology that automatically slows down and

stops the following vehicles in the case of a device failure or an interruption of the platoon by general vehicles.

3.3 Efforts for the introduction of truck platooning

Since FY2014, the Japanese government has published the Public-Private ITS Initiative/Roadmap every year, which shows future strategies and direction of ITS and automated driving(Strategic Conference for the Advancement of Utilizing Public and Private Sector Data and Strategic Headquarters for the Advanced Information and Telecommunications Network Society, 2019). The 2018 edition set the target year to realize the commercialization of truck platooning: 2021 for manned following vehicles and 2022 for unmanned following vehicles. With a view to achieving these targets, the 2019 edition showed more specific details for the operation of truck platooning and the direction of technical development, such as driving technique, driving responsibility, control of following vehicles, driving procedures, etc.

• *Initiatives toward the commercialization of truck platooning*
The Joint Public-Private Sector Council consisting of the national government, vehicle manufacturers, and transportation companies, shared awareness and discussed the issues for the commercialization of truck platooning(Joint Public-Private Sector Council for Commercialization of Truck Platooning, 2019). Following the interim report published in March 2019, three phases are considered for the commercialization of truck platooning: Phase 1, Introduction of platooning with manned following vehicles; Phase 2, Development of platooning with manned following vehicles; and Phase 3, Platooning with unmanned following vehicles. Phase 1 uses CACC and LKA to follow the leading vehicle. And, if the leading vehicle changes lane, the driver of the following vehicle must follow the leading vehicle and operate his/her vehicle. In Phase 2, the automatic lane change function was added to those in Phase 1.

Among these, Phase 1, Introduction is already technically available for implementation in society. Driving on public roads is already permitted under the current laws. Advantages in saving fuel and cost are expected to encourage the adoption by individual companies. To realize it, however, further verification is required to prove the advantage in reducing the driver's burden regarding the following vehicles.

On the other hand, it takes some time to develop and market commercially feasible vehicles for truck platooning with unmanned following vehicles. There are many remaining issues that require further study, such as the development of new transportation infrastructure, driving rules, and operational models. The efforts to resolve these issues need to be steadily promoted. Accordingly, we should first realize truck platooning with manned following vehicles (Phase 1, Introduction and Phase 2, Development) and then by applying such technical development to Phase 3, Platooning with unmanned following vehicles.

• *Initiatives toward developing traffic rules for truck platooning*
Aiming to realize truck platooning with unmanned following vehicles the government outlined the traffic rules for truck platooning, such as inter-vehicle distance, driving lane, and number of vehicles in a platoon while traveling on an expressway, as follows(MIRI, 2019).

- Number of vehicles is up to 3. For the time being, 4 vehicles are not assumed.
- Inter-vehicle distance is up to 10 meters. In the future, it is expected to be reduced.
- Traveling speed is at maximum: 80 km/h; minimum: 50 km/h.

- Formation/deformation of a truck platoon shall be done while halting vehicles in SA, PA, or designated area.
- As a safety measure in case of interruption of electronic towing, vehicles other than the leading vehicle must automatically and safely stop on road shoulders and the like. And, when merging into the main lane, safety measures should be taken to prevent easy interruption by other vehicles.

• *Initiatives toward the development of infrastructure for truck platooning*

To realize truck platooning, Platoon Formation Centers(PFCs) that is dedicated facilities for formation/deformation of a truck platoon and rest facilities for truck drivers are required(Watanabe et al., 2021). These facilities need to be developed in a location directly connected to the main line of expressways. In the early stage of truck platooning with a limited number of trucks engaged in platooning, existing rest facilities may be utilized. The interim report recommended that large-scale facilities directly connected to the expressway should be developed in the future(MLIT, 2019b). The report further recommended developing the PFCs in each of the Tokyo, Nagoya, and Osaka regions, and multiple rest facilities in the vicinity of Shizuoka Prefecture. Topics of discussions toward the development of infrastructure for truck platooning are as follows:

◆ Items currently applied toward the commercialization of truck platooning with unmanned following vehicles:
- Traveling space is mixed with general vehicles and logistics vehicles.
- As for rest facilities, expansion of parking spaces, introduction of reservation system, etc.
- As for merging/branching zones, driving assistance by providing information at the merging zone to the main line.
- As for PFCs, connected area, smart IC directly connected to the private facilities, etc.
- Information provision to traveling vehicles.
- Maintenance of traffic safety facilities and pavement, etc.

◆ After the commercialization of truck platooning with unmanned following vehicles, conditions below need to be considered:
- As for traveling space, securing a dedicated traveling space, and spatial reorganization including the use of parallel routes.
- As for rest facilities, development of dedicated parking spaces, and direct connection to a dedicated traveling space.
- As for merging/branching zones, traffic control at the merging zone to the main line, and ramp directly connected to a dedicated traveling space.
- As for PFCs, use of existing rest facilities, and development of facilities directly connected to dedicated driving spaces.
- Creation of operation schedules and matching of truck platooning, etc.

4. Comparison of initiatives for HCVs between Europe and Japan

4.1 Introduction of HCVs in Europe

In Europe, the total length of large freight vehicles is mostly 25.25 meters, the total weight restriction, around 60 tons, varies in each country(ITF, 2019). In particular, the Nordic countries are progressing in regulatory relaxation in terms of total length and gross weight. As for development phases of HCV introduction in Europe, four scenarios may be considered: Phase 1, Maintaining the status quo (i.e., EU-standard, that is, total length: 18.75m, gross weight: 40-44 tons); Phase 2, Introduction of a total length of 25.25 meters (still with

restrictions on gross weight); Phase 3, Introduction of performance-based standards (PBS); and Phase 4, Full introduction (total length: 25.25 meters; gross weight: 60t). Table 3 shows these HCV introduction scenarios in major European countries together with the Japanese situation. Japan is similar to Germany. Sweden is further shifting to Phase 3, Introduction of PBS. With the progress of the FALCON project currently under study in Europe, a standardized regulation, if developed based on PBS, may have a significant impact. Japan, on the other hand, does not expect significant relaxation of weight restrictions. Therefore, the introduction of PBS may be an option.

Table 3 - Summary of examples of HCV introduction in major countries

Country name	Scenario	Current situation
Sweden	4. Full introduction (25.25m; 60t)	-Weight restrictions relaxed up to 74t (on some roads, PBS) -Full length restrictions relaxed up to 34.5m under study
Netherlands	4. Full introduction (25.25m; 60t)	-Improvement of cross-border transportation from/to the neighboring country (Belgium)
Germany	2. Introduction of 25.25m(with restrictions on the weight)	-Weight restrictions relaxed: complex transportation (railway/water transportation) only -Expansion of service area
Japan	2. Introduction of 25.25m(with restrictions on the weight)	-Weight restrictions relaxed: None -Expansion of service area
UK	1. Maintaining the status quo (EU-standard)	-Field operational test with 18.75m semi-trailer in progress

(Source: Prepared by authors based on ITF, 2019)

4.2 Findings on the issues of HCVs in Japan

We conducted an interview survey (hereinafter, "domestic survey") on the current issues with some of the parties who participated in the field operational test of HCVs in Japan. The domestic survey was conducted by interviewing with two logistics companies, one truck manufacturer, one trailer manufacturer, and one expressway management company. For the issues obtained from this survey, we summarized the suggestions from our findings from the cases in Europe as follows.

(1) Expansion of parking facilities

In the domestic survey, several logistics companies requested this matter. To respond to this request, the road administrators are currently expanding parking lots for HCVs in major SAs and PAs. In the future, additional measures including the improvement of the operation of existing facilities, such as the development of parking spaces specialized for rest, introduction of a reservation system based on a pay-per-use system, and promotion of the use of parking lots outside the expressway, may be considered. In Europe, Sweden has developed parking facilities over a long time. Germany conducted the intelligent compact parking pilot, a demonstration test of an advanced reservation system that assures drivers a secured parking space(BASt, 2017). These findings suggest that Japan faces the same challenges as Europe.

(2) Expansion of traveling sections

In the domestic survey, the need to expand the HCV traveling sections to nationwide expressways and major highways, as well as to improve the operation of the special vehicle

system to enable the passage of urban expressways such as the Metropolitan Expressway, was expressed. On the other hand, concerns were raised about terrain (slowing down due to lack of engine horsepower on steep slopes) and weather conditions (snowfall and icy roads). In Germany, due to road traffic conditions, traveling sections are mostly restricted in urban areas. The survey in Sweden shows that more HCV accidents occur in winter(ITF, 2019). The PBS in Europe includes the examination of driving conditions in winter and the road level unique to Europe. Thus, for the introduction of PBS in Japan, we think it is important to select the evaluation items in consideration of Japan's topography and road conditions.

(3) Deregulation of gross weight

In Japan, the Vehicles Regulations Order based on the Road Act stipulates that the gross vehicle weight (GVW) of general heavy-duty trucks (12-m vehicles, 10-t trucks) is 25 tons, while the gross combination weight (GCW) of HCVs (vehicles with a total length of over 21 meters) is 44 tons. An opinion in the domestic survey suggested the relaxation of gross weight restrictions. To secure a load capacity equivalent to that of two 12-m vehicles (maximum load capacity: 13 tons), a slight (about 1 to 2 tons) relaxation of GCW of vehicles with a total length of over 21 meters (maximum load capacity: 25.9 tons) can improve the load capacity. On the other hand, regarding the impact on road infrastructure such as bridges and road surfaces, the Road Act stipulates the strength required for road structures. Therefore, the axle load and wheel load stipulated in the Vehicles Regulations Order and the Maintenance Standards of the Road Trucking Vehicle Act must be considered. In Europe, road types are established according to the load capacity of bridges and the like in Sweden, and the impact on road infrastructure is included in the evaluation items of the examination of PBS scheme in Europe(De Saxe, et al. 2018). We, therefore, think it is important to consider the introduction of PBS, which includes the impact on road infrastructure in consideration of the durability of Japanese bridges and pavements as an evaluation item.

(4) Diversification of HCV types

Japan currently limits the vehicle type to one type: a van-type rigid truck with a trailer, which was introduced based on the MLIT field operational test. In the domestic survey, the expansion of trailer types was requested. In Europe, various trailers have been introduced(Steer, et al., 2013). In addition, the PBS study in the EU covers HCV types that combine various trailers(De Saxe, et al. 2018). Thus, we think it is important to consider the introduction of PBS in Japan for HCV types in consideration of Japan's transportation conditions.

(5) Promotion of joint transportation

Our domestic survey also noted an opinion that a single company may not secure cargoes sufficient to operate HCVs. Currently in Japan, while major special assortment freight forwarders are operating joint transportation as described in Section 2.3, the development of an information-sharing platform is underway to accelerate matching involving shipper companies. Therefore, to expand joint transportation that meets the needs of various freight transportation in Japan, we think it is important to make efforts such as (2) expansion of traveling sections and (4) diversification of HCV types as above.

5. Comparison of efforts for truck platooning between Europe and Japan

5.1 Truck platooning in Europe

In Europe, various field operational tests on truck platooning have been conducted, some of which were joined not only by truck manufacturers but also by logistics companies. For

instance, in Germany, major logistics companies participated in the tests to research the effects of platooning on driver's stress(Hochschule Fresenius et al., 2019).

ENabling SafE Multi-Brand pLatooning for Europe (ENSEMBLE) is a project that aims to realize multi-brand truck platooning on public roads(Willemsen, et al. 2018). The project, participated in by six European truck manufacturers, public organizations, etc., aims to develop a common communication system in addition to the platooning system of each manufacturer, thereby creating a white brand truck that all manufacturers can operate. To expand truck platooning, the project emphasizes early introduction and subsequent gradual development. The project also takes a strategy that does not pursue rapid full automation by prioritizing improvement of the driver's working environment. Furthermore, to realize platooning, the project emphasizes the need for a business operator called a platooning service provider, who operates and manages IT infrastructure, manages truck operation data, and operates and manages matching and profit-sharing mechanisms.

A brief comparison of initiatives to realize truck platooning between Europe and Japan produces the following summary. Regarding truck platooning with unmanned following vehicles, tests are underway in Japan for its realization, while no specific study has been conducted in Europe. Regarding multi-brand platooning, Japanese truck manufacturers apply common vehicle technology, while European truck manufacturers are making efforts to internationally standardize vehicle technology. In addition, Europe is ahead in participation of major logistics companies in tests, understanding of the merits of logistics companies through experiments using existing driver assistance systems and in analysis of the effects of driver stress, etc. Table 4 shows the comparison of the platooning rules in the initial phase between Europe and Japan. Despite slight differences in the number of vehicles and the inter-vehicle distance, they are almost the same.

Table 4 - Comparison of platooning rules in the initial phase between Europe and Japan

	Europe: ENSEMBLE level A	Japan: Phase 1, Introduction
Number of vehicles in a platoon	Up to 7 (for verification)	Restricted up to 3
Traveling speed	—	Maximum speed: 80 km/h
Inter-vehicle distance	About 18 meters (0.8 s, 80 km/h) or less	About 10 meters (0.5 s, 80 km/h) or more
Automation	Manned following vehicles (SAE level 2)	Manned following vehicles (SAE level 2)

(Source: Prepared by authors based on Willemsen, et al., 2018; Joint Public-Private Sector Council for Commercialization of Truck Platooning, 2019; MIRI, 2019)

5.2 Findings on the issues of truck platooning in Japan

We summarize the measures to expand platooning in Japan, by considering the current state of efforts in Europe described so far. The most important points are as follows:

(1) Implementation of tests in comercial freight transportation
European tests are joined by logistics companies to try truck platooning with actual freight. It is also necessary to verify the technology from the perspective of the logistics companies, such as the effect of truck platooning on the psychological burden of truck drivers.

(2) Promotion of joint transportation

By conducting joint transportation by multiple logistics companies, it is possible to increase the chances of matching trucks available for platooning. For this purpose, we need to establish a platoon service provider to coordinate operation routes and schedules among multiple logistics companies and design a system such as platoon matching, operation schedule coordination, and profit sharing.

(3) Truck platooning with unmanned following vehicles
Based on the rapid progress of autonomous driving in recent years, it is important to review laws and regulations that consider the characteristics of truck transportation such as working conditions, transportation responsibilities, and the cargo impacts, etc.

(4) Infrastructure development
Aiming to commercialize truck platooning with unmanned following vehicles in 2022, the development of truck platooning facilities in and near expressways has been also considered. On the other hand, European countries mainly focus on truck platooning with manned following vehicles, without specific studies on the development of infrastructure toward the realization of unmanned platooning. From the above, we think it is necessary to address the issue of infrastructure development, which is relatively advanced in Japan. At the same time, it is important to consider the development of formation/deformation facilities assuming the use of both truck platooning and HCVs.

6. Conclusions

This paper unveils the current situations and issues on HCVs and truck platooning in Japan through not only literature research but also interviews with persons involved in the field operational test. In addition, the authors summarized suggestions for future logistics measures in Japan through a comparison between Japan and Europe.

As for HCVs, Europe has already introduced many types and been moving towards further deregulation. In a research project aimed at promoting the expansion of HCVs in Europe, they are studying the combination of vehicle types and traveling sections by using a scientific analysis method called PBS that considers the driving characteristics and the load on the infrastructure. On the other hand, since 2019, Japan has officially introduced HCVs (vehicle length of over 21 meters) by relaxing the regulatory restriction of total length of heavy vehicles to 25 meters. Japan is similar to Germany in HCV introduction, which did not relax gross weight but conditionally relaxed total length (restrictive introduction).

As for truck platooning, in Europe, truck platooning with unmanned following vehicles has yet to be specifically studied on public roads. Japan uses a common system among domestic manufacturers, thus enabling multi-brand platooning among domestic manufacturers. Regarding platooning automation level, the inter-level functions are almost the same between Europe and Japan. In addition, Europe is ahead in the effort for international standardization among multinational truck manufacturers, participation of major logistics companies in tests, understanding of the merits of logistics companies through experiments using existing driver assistance systems and in analysis of the effects of driver stress, etc.

As a suggestion for future logistics measures in Japan, the expansion and development of parking facilities for HCVs is urgently needed. Measures installable by improving the operation of existing equipment, such as the development of parking spaces specialized for rest and the introduction of a reservation system based on a pay-per-use system should also be

adopted. In addition, for further expansion of traveling sections, the field tests that consider road conditions with slopes and weather conditions in winter should be also expanded. For that purpose, the study of the combination of vehicle type and traveling section by using scientific analysis considering the driving characteristics and the load on the infrastructure such as PBS should be considered. On the other hand, as an effort to realize the commercialization of truck platooning with manned following vehicles, the related actions, such as establishment of a platooning service provider for joint transportation by multiple logistics companies, and promotion of international standardization for platooning by multi-brand, is needed. Further, for early realization of unmanned platooning, based on the rapid progress of autonomous driving in recent years, the development of platooning infrastructure and study of regulations that consider the characteristics of truck transportation, such as working conditions, transportation responsibility, and impact of cargoes, are important. In case of full-scale implementation of both HCVs and truck platooning, creation of platoon formation/deformation facilities(PFCs) may enable the traveling of HCVs on expressways only. Therefore, there is no need to apply for a special vehicle permission, and dollies for HCVs can be stored and shared. In addition, traveling permission for HCVs on the platoon-dedicated lane can realize significant improvement in driving safety.

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7. References

- De Saxe, C., Kural, K., Schmidt, F., Van Geem, C., Kharrazi, S. Berman, R., Cebon, D. and Woodrooffe, J.(2018), Definition and Validation of a Smart Infrastructure Access Policy utilising Performance-Based Standards, D3.1/5/6, FALCON.
- European Automobile Manufacturers' Association (ACEA)(2017), "EU Roadmap for Truck Platooning".
- Federal Highway Research Institute(BASt)(2017), Intelligent compact truck parking, https://www.bast.de/BASt_2017/EN/Traffic_Engineering/Subjects/compact-parking.html.
- Hochschule Fresenius, DB Schenker and MAN Truck & Bus(2019), "EDDI: Electronic Drawbar-Digital Innovation", Project re-port-presentation of the result.
- International Transport Forum(ITF) (2019), High Capacity Transport: Towards Efficient, Safe and Sustainable Road Freight, International Transport Forum Policy Papers, 69, OECD Publishing.
- Janssen, R., Zwijnenberg, J., Blankers, I. and De Kruijff, J.(2015), "Truck Platooning-Driving the Future of Transportation", TNO 2014 R11893.
- Joint Public-Private Sector Council for Commercialization of Truck Platooning(2019), An interim report of The Joint Public-Private Sector Council for Commercialization of Truck Platooning. [in Japanese]
- Ministry of Land, Infrastructure, Transport and Tourism(MLIT)(2019a), https://www.mlit.go.jp/road/double_renketsu_truck/.
- Ministry of Land, Infrastructure, Transport and Tourism(MLIT)(2019b), Reports of the Study Group on Utilization of Expressway Infrastructure Corresponding to New Logistics System.[In Japanese]

- Mizuho Information & Research Institute, Inc.(MIRI) (2019), Research Report on the Realization of Automated Driving in Accordance with the Direction of Technological Development, Research Study Commissioned by the National Police Agency. [in Japanese]
- New Energy and Industrial Technology Development Organization(NEDO)(2013), Energy ITS Promotion Project: Research and Development for Cooperative Driving (Automatic Driving), FY 2008-2012 Outcome Report, 2013. [in Japanese]
- Steer, J., Dionori, F., Casullo, L., Vollath, C., Frisoni, R., Carippo, F. and Ranghetti, D.(2013), A review of Megatrucks, European Commission Directorate General for Internal Policy, Publications Office of the European Union.
- Strategic Conference for the Advancement of Utilizing Public and Private Sector Data and Strategic Headquarters for the Advanced Information and Telecommunications Network Society(2019), Public-Private ITS Initiative/Roadmaps.
- Toyota Tsusho(2018), R&D and Field operational test for Social Implementation of Advanced Automatic Driving Systems: Demonstration for Social Implementation of Truck Convoy Driving, Research report commissioned by the Ministry of Economy, Trade and Industry. [in Japanese]
- Truck Platooning Initiative(2020), https://truck-platooning-initiative.com/
- Tsugawa, S.(2013), An Overview on an Automated Truck Platoon within the Energy ITS Project, IFAC Proceedings, 46, 41–46.
- Watanabe, D., Kenmochi, T. and Sasa, K.(2021): An Analytical Approach for Facility Location for Truck Platooning-A Case Study of Unmanned Following Truck Platooning System in Japan-, Logistics, 5(2), 27, https://doi.org/10.3390/logistics5020027.
- Willemsen, D., Schmeitz, A., Fusco, M., Jan van Ark, E., van Kempen, E., Soderman, M.;, Atanassow, B., Sjoberg, K., Nordin, H., Dhurjati, P.(2018), Requirements Review from EU projects, D2.1 of H2020 project ENSEMBLE.