New approaches for heavy vehicle traffic management using ETC2.0

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Abstract
In Japan, measures for addressing the aging of road infrastructure are a pressing concern. In particular, vehicles exceeding load limits have a large effect on the degradation of road infrastructure, so proper road use by heavy vehicles is needed. However, the efficiency of distribution needs to be improved by addressing the increasing size of vehicles and lessening the burden on freight operators. This report describes the use of ITS technologies in initiatives for optimizing heavy vehicle traffic while simultaneously smoothing its distribution and making it more efficient.

Keywords:
heavy vehicle, ETC2.0, privilege measures

1. Introduction
In Japan, over roughly the next 10 years, measures to cope with the aging of public infrastructure constructed during the period of strong economic growth are becoming a pressing concern. For example, over 40% of bridges are more than 50 years old[1]. In addition to appropriate maintenance and repair, heavy vehicle traffic, which has a large effect on road deterioration, must be controlled. In particular, vehicles that greatly exceed the weight limit have a substantial effect on the deterioration of road infrastructure, and a system for controlling specially permitted commercial vehicles has been established. [5] However, with the implementation of efficient logistics due to support for heavy vehicles and more rapid approval procedures, there is demand for further transit controls by toughening laws against malicious violations by vehicles[2].

Information and communication technology (ICT) has advanced rapidly, it has become more widespread and is used in a wide variety of situations in society. In road traffic
management, the increased speed and capacity of communication technology has been accompanied by advances in two-way communication, such as information collection by vehicles, in addition to information provision by road administrators. For road traffic in Japan, the new ETC2.0 service, which utilizes dedicated short-range communication was started in 2014. Along with providing electronic toll collection system (ETC), safe driving assistance information, and traffic jam avoidance assistance information, ETC2.0, which was developed as a cooperative intelligent transport system (ITS), also introduces new services that utilize the road information collected by vehicles. The number of ETC2.0 on board units (OBU) is now around 1.3 million, as of the end of July 2016[3]. In the future, this ICT will continue to build infrastructure that can employ new measures for controlling road traffic. MLIT is working on initiatives to achieve more efficient, smoother cargo vehicle logistics while also controlling the transit of heavy vehicles through the use of ITS technology.

In this paper, we review the initiatives and problems with heavy vehicle transit control measures in Japan, and overseas trends in the introduction of ITS technology into heavy vehicle transit control measures. We also report on new initiatives for heavy vehicle traffic management utilizing ETC2.0 in Japan.

2. Domestic and International Trends in Heavy Vehicle Traffic Management

2.1 Current Status and Problems in Japan

(1) System for controlling specially permitted commercial vehicles

In Japan, to encourage appropriate road use, a system for controlling specially permitted commercial vehicles was introduced with the aim of controlling the transit of heavy vehicles based on Article 47-2 of the Road Act[5].

To reduce the burden of the application process on freight operators an online application system began in March 2004, and in 2009 the permit period, which had been a maximum of 1 year up to that point, was extended to 2 years. To handle heavier vehicles, measures were taken, such as revising the permissible upper weight limit for articulated road trains carrying international shipping containers, and abolishing permits for the transit of total weight or vehicle heights in excess of the limit values on designated weight roads and designated height roads. Furthermore, nationally specified permission route for large vehicles were designated based on the amendments to the Road Act made in 2013, and from October 2014, if vehicles traveled in only these zones, the application decision and permit issuing process, which previously took around 20 days, was reduced to around 3 days through centralized decision making by the national government[6].

Furthermore, to strengthen regulations, a system of issuing guidance warnings based on measurement results from weigh-in-motion (WIM) began in 2008, and a system of publishing the details of infractions by operators with repeat transit violations began in 2013[7].
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(2) Specially permitted commercial vehicles violation testing

When driving specially permitted commercial vehicles, although it is necessary to apply for permits from the road administrators in advance, there are cases where vehicles do not have permits or they are driving under conditions different from those allowed by their permit. Therefore, road administrators must identify violating vehicles. In general, guided testing is conducted periodically at guided testing stations (Figure 1).

![Figure 1 Photograph of testing](source: Hokuriku Regional Development Bureau website)

However, there are limits on the number of vehicles that can be caught in this way, because of problems obtaining space for guided testing stations; thus, it is difficult to perform guided testing efficiently. Therefore, MLIT which manages the national roads directly, has set up WIM at main bases and also performs testing online. The ministry also formulates and publishes government guidance, cancels permits, and prosecutes people who repeatedly drive specially permitted commercial vehicles illegally.

(3) WIM(weigh-in-motion)

WIMs were installed in 41 locations (as of the end of July 2016) on directly managed national roads. MLIT is planning to deal with operators who have been identified by WIM as repeatedly driving in violation by sending them guidance warnings.

WIMs have a vehicle detection function, a roadside processing function, a vehicle information acquisition function, and an axle weight measurement function. The units measure the total vehicle weight, axle weight, and number of axles, and take an image of the number plate and vehicle. For vehicles that exceed the maximum limits stipulated by the paragraph 1 in Article 47 of Road Act and the Article 3 of Cabinet Order on Vehicle Restriction, the vehicle information is obtained and the measurement results are sent to center equipments. Figure 2 shows a schematic of WIM.
(4) Problems

Although a system for controlling specially permitted commercial vehicles has improved, including strengthening testing for violating vehicles and reducing the burden on applicants, the following problems remain.

First, testing for violators is insufficient. In the measurement results from the WIM of MLIT for 2011[7], 33% of heavy vehicles exceeded the total vehicle weight written on the vehicle inspection certificate, and there were vehicles where the axle weight exceeded 10 tons. In other words, many heavy vehicles drive overweight in violation of a system for controlling specially permitted commercial vehicles, and to control transit, there is the problem of efficiently strengthening testing for these violators under tight fiscal circumstances. However, for pull-in inspections in weight measurement stations, it is difficult to increase the number of vehicles pulled in and the number of inspections conducted, owing to limitations on personnel and space for pull-in stations. Because the locations of stations are fixed, there are problems with avoidance behavior among violating transit vehicles after inspections begin and increasing the burden on compliant vehicles.

For compliant users, the burden on freight operators and the cost of approval work on road administrators should be reduced by further simplifying and speeding up application and approval procedures, and making advances in creating mechanisms for easily performing periodic checks of permit certificates, which are currently submitted on paper. Furthermore, rationalizing and revising permit standards to support heavier vehicles by using bridge inspection result data and monitoring of vehicle driving status will be an important problem for the future.

Elsewhere in the world, these problems have been tackled by utilizing ITS technology, and the following section summarizes cases that are relevant for Japan.
2.2 Examples of ITS Technology for Heavy Vehicle Transit Control outside Japan

(1) USA

In the USA, pull-in and stationary weight measurement inspections are typically conducted at weight measurement stations at state lines. However, vehicles waiting for inspection cause traffic problems and increase logistics costs; therefore, the PrePass service has been established to avoid inspection by pre-screening with ITS technology. When heavy vehicle operators register to use the PrePass service, they are required to show that they satisfy the driving certificate requirements and submit a safety evaluation performed by the Federal Motor Carrier Safety Administration (FMCSA), which is the agency responsible for transportation in the USA. The heavy vehicles of operators who participate in the PrePass service can use the inspection bypass service at over 300 weight measurement stations in various locations (31 states) in the USA. In inspection bypass services, the probability of getting pulled into a weight measurement station varies depending on the FMCSA safety evaluation score of the operator; the lower the score the higher the probability of getting pulled in. Every year, over 50 million vehicles (as of 2012) use pre-screening with the PrePass service, with approximately 68,000 operators and a total of approximately 500,000 heavy vehicles using the service (as of February 2015).

The HELP, Inc. organization that operates the PrePass service also operates the PrePass Plus service in conjunction with E-ZPass, which provides toll road and bridge electronic fee collection services. The PrePass Plus service allows operators to use the E-ZPass electronic fee collection facilities via the OBU and usage fee payment account of the PrePass service. This is an example of the implementation of cooperative ITS in which multiple ITS services can use a single OBU.

(2) Korea

In Korea, although testing is widely performed by personnel at weight measurement stations, there are plans to set up the automatic high-speed weigh-in-motion (WIM) method, which combines automatic weight measurement with cameras for vehicle model identification. Currently, mobile testing teams develop and carry out testing plans by considering the driving properties of heavy vehicles based on the judgment of the team leader. In the future, it is expected that a system will be built to create national testing plans by using data obtained from the planned high-speed WIM system. Furthermore, there is a policy to use the data collected by the high-speed WIM system in pavement, traffic, and bridge management systems.

Furthermore, in Korea, information such as the starting point and destination point of the route that the heavy vehicle will travel, the type and category of vehicle, and the cargo is submitted during the permit application, as in Japan, and an online application system is used for most applications. There are plans to introduce a mechanism of information distribution to check the permit data of the applicant online using a smartphone after an online permit has
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been issued[8].

(3) Australia

In Australia, the size and train length of logistics vehicles have been increasing due to a driver shortage arising from strong resource trading and economic growth. To mitigate the effects of overweight vehicles on road infrastructure and particularly on bridges in this large country, a new heavy vehicle transit management program called the Intelligent Access Program has started operating in addition to the existing transit permit system[9]. This program is a voluntary system that remotely monitors transit conditions and notifies the governing agencies of violations by using OBU that have Global Navigation Satellite System (GNSS), weight measurement, and communication functions. Vehicles that participate in this program enjoy relaxed transit conditions such as increased regulated weight values. Furthermore, the OBU used in this program can also be used for private services, which provides a framework for various private services, such as service providers who have been certified by a public certification authority to create driving logs, and for the government service for transit condition monitoring.

The mechanism for heavy vehicle management using the onboard weight meter in this program is an improvement on the international standardization work of the ISO15638 (TARV) series in the ISO/TC204, which stipulates international standardization related to ITS, standardization of applications for vehicle weight monitoring (part 12), and management and testing of heavy logistics vehicles by governments (part 13)[10].

(4) Europe

To provide safe, equitable road transport in Europe, in 1985 The European Commission brought in legislation to require trucks carrying 3.5 tons or more and buses with nine passengers or more to carry a tachograph (analog), and EC regulation No. 561/2006 was enacted in 2006 requiring new vehicles to carry digital tachographs. However, because testing for unauthorized usage and counterfeits is costly, EU regulation No. 165/2014 enacted in 2014 now specifies that smart digital tachographs must be fitted in new vehicles sold in and after 2018 and must be fitted all relevant vehicles by 2030. The digital tachograph has a built-in GNSS module and road-vehicle communication function that can be accessed remotely by testing agencies during driving[11]. These smart tachograph specifications also contain the possibility of introducing a communication interface for communicating data with onboard weight measurement units. Consequently, it is expected that heavy vehicle manufacturers in Europe will be able to record the measurement data from current onboard weight meters with smart tachographs, and to build mechanisms for testing agencies to check the vehicle weight by accessing the data remotely via road-vehicle communication.
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(5) Czech Republic
In the Czech Republic, distance charges on heavy cargo vehicles were introduced in 2007 using dedicated short-range communication. Furthermore, a system that implements direct enforcement, which imposes penalties directly by using high-precision WIM, has been introduced. Although the initial investment in this system is large, it can detect and impose penalties on violating vehicles through continuous vehicle monitoring, and increases the efficiency of human testing. Automatic vehicle weight measurement units are a better method than manual testing for efficiently catching the continuously increasing number of weight-violating vehicles.

To introduce this system, the Czech Republic amended the weight measurement law (Legal Frame of Metrology) in 2010. The Czech Metrology Institute began testing the measurement precision of the legal measurement instruments designated by the Ministry of Industry in 2011, and type approval certification was issued, and the direct enforcement automatic vehicle weight measurement units began operation in 2012. Currently, WIM for direct enforcement has been installed at two locations.

3. Features of ETC2.0 in Japan
3.1 Functions and Advantages of ETC2.0
ETC2.0 OBU can collect probe data from vehicles by using high-speed high-capacity communication between the OBU and roadside units. Furthermore, the units are tamper-resistant, which provides security against unauthorized use. ETC2.0 probe data include vehicle position information obtained by the GNSS positioning function, which makes it possible to determine the driving route of a vehicle. Previously, checking the driving routes and weights of heavy vehicles based on a system for controlling specially permitted commercial vehicles could only be performed at WIM and testing stations. In contrast, with ETC2.0, the driving route of heavy vehicles can be determined two-dimensionally, and the weights of heavy vehicles can also be determined two-dimensionally by attaching weight measurement data obtained from the automatic vehicle weight measurement unit to the driving route information obtained from the ETC2.0 probe data. The scope of monitoring heavy vehicle traffic can be expanded at low cost, and this should contribute to transit control, namely, to preserving and extending the life of road infrastructure. NILM has started developing a heavy vehicle monitoring system that uses these functions of ETC2.0 and efforts for new heavy vehicle traffic management. Details of these efforts are described in Section 4.

3.2 Mechanisms for Collecting ETC2.0 Probe Data
ETC2.0 probe data are travel record, behavior record and others, which are stored in the ETC2.0 OBU. The driving history consists of information including the time, latitude, and longitude, and the driving route of the vehicle can be determined from this information. The latitude and longitude information is obtained by the GNSS positioning function of the OBU.
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The driving history is recorded after the vehicle has driven 200 m from the last recorded point or when the driving direction changes by 45° or more. The ETC2.0 OBU can save the driving history for driving distances of about 80 km. ETC2.0 probe data are uplinked to ITS spots, which is a roadside unit antenna (range of approximately 20 m directly underneath), when the vehicle passes through the communication range. The uplinked ETC2.0 probe data are collected and stored on a probe integrated server, and can be used by road administrators (Figure 3).

ETC2.0 probe data cannot identify individual vehicles normally. But, in the simplified system for controlling specially permitted commercial vehicles which has run by MLIT since January 2016, it is collecting specific probe data which can identify individual vehicles from agreed freight operators. In Japanese the system called "TOKUSHA-GOLD".

● Probe data stored in the ETC2.0 OBU is uplinked when the vehicle passes under an ITS Spot.

Figure 3 Overview of Probe data collection in ETC2.0

4. New Heavy Vehicle Traffic Management Using ETC2.0
4.1 Development of the Heavy Vehicle Driving Monitoring System Using Probe Data

The heavy vehicle monitoring system can collect data on vehicles that exceed limit values when they pass automatic vehicle weight measurement units, and specific probe data, including driving history, can be collected from vehicles passing roadside units (e.g., ITS spots) around the country. This system monitors the following: vehicles driving in violation of their permits; vehicles driving permitted routes; the weights of heavy vehicles passing through automatic weight measurement units; the number of guidance warnings issued; the number of malicious operators; and the number of good operators. The monitoring is performed by using road map data based on the data from automatic vehicle weight measurement units around the
country, heavy vehicle specific probe data, permit and vehicle inspection certification data, and guided testing record data for station testing (Figure 4).

![Diagram of Heavy Vehicle Driving Monitoring System]

**Figure 4 Overview of the heavy vehicle driving monitoring system**

### 4.2 Measures for Installing and Expanding Heavy Vehicle Traffic Monitoring

Monitoring of driving conditions by ETC2.0 requires vehicles to be equipped with OBU. Therefore, as the number of vehicles subject to monitoring increases, measures for promoting more widespread use of OBU are needed. One measure for promoting OBU is to give vehicles equipped with an OBU preferential treatment. For example, monitored vehicles are given incentives in Australia and the USA.

In July 2015, MLIT published measures of simplifying the transit permit procedures for heavy vehicles equipped with ETC2.0. And then, "TOKUSHA-GOLD" system had started since January 2016. In the system for controlling specially permitted commercial vehicles, people driving specially permitted commercial vehicles need to apply for a permit for each individual transport route between each start and end point. Furthermore, during the journey, they are required to drive on only the permitted individual transport routes. In contrast, in the TOKUSHA-GOLD system, if a vehicle equipped with ETC2.0 drives in the nationally specified route permission for large vehicles, they can freely choose their route, enabling more efficient, smoother transport (Figure 5).
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**Current**
- Permission for route by route
- Allowing to travel on only permitted routes.

**ETC 2.0 equipped HV**
- Easy to recognize the routes of by ETC2.0.
- Permission for multiple routes

![Figure 5 Overview of “TOKUSHA-GOLD” system](image)

It is expected that vehicles equipped with ETC2.0 will be exempt from pull-in inspections in testing stations, and the operational status will be checked from outside the vehicle through communication with roadside units. Therefore, testing stations can detect whether passing heavy vehicles are equipped with ETC2.0, and perform selective, focused testing. This will reduce the testing burden on freight operators and reduce the cost of running testing schemes.

In heavy vehicle traffic monitoring by ETC2.0, freight operators bear the cost of installing OBU. However, the preferential treatment of vehicles carrying an OBU is an incentive to operators to participate in monitoring. This incentive should increase the number of vehicles subject to heavy vehicle traffic monitoring by ETC2.0; reduce the testing cost for road administrators; reduce the maintenance, management, and upgrade costs of road infrastructure; and reduce the administrative costs of freight operators (Figure 6).

![Installing onboard unit](image)

**The effective management of the violation vehicle by ITS technology**
- The effective extension of WIM
- Pre-screening
- Punishment (Red card, Cancellation of the incentive, Discount stop)

![Figure 6 Expansion of heavy vehicle traffic monitoring](image)
5. Future Expansion

5.1 Provision of the Vehicle Transit Permit Information

The vehicle transit permit information is expected to be provided as part of the expansion of heavy vehicle traffic management. This will provide information, such as transit permit routes and transit permit conditions, to tablet PCs for freight operators who have vehicles that drive in nationally specified permission route for large vehicles. Transport managers and drivers could check their own permit routes and permit conditions on screen. This method is based on the Korean example of permit data being accessed online using smartphones.

It is envisioned that freight operators will use the provided transit permit route and transit permit conditions to plan driver routes based on traffic rules and traffic congestion before setting out, and check the driving route and establish future transit plans by overlaying the actual driving route after transport. Furthermore, if the driver needs to alter the route specified in the application because of road traffic rules or traffic congestion while driving, they can select a route to suit the road traffic conditions to allow for safe driving.

Although the road administrators must bear the cost of constructing the system, it may reduce the burden on applicants and road administrators; the road administrators will be able to search for permit information quickly during violation testing by using the system. Furthermore, providing permitted routes to the driver should allow them to avoid mistakenly driving on roads with low structural strength or maintenance management standards, which will reduce the deterioration of vulnerable road structures and bridges.

6. Conclusion

In this paper, we reviewed the approaches and problems with past heavy vehicle transit control measures in Japan, analyzed examples of ITS technology used for heavy vehicle transit control measures outside Japan, and extracted points that should be used as a reference for Japan. We also reported on approaches to achieve more efficient, smoother heavy vehicle transit control and logistics by using ETC2.0 for heavy vehicle traffic management in Japan. Big data, namely, the large amount of probe data and vehicle weight information that can be collected by heavy vehicle transit monitoring, is also expected to be used in road structure maintenance and management, and will also advance research into future methods of managing road use.

7. References

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