Applicability for Monitoring Weight of Heavy Vehicles with Onboard Mass Unit

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ABSTRACT

The weights of the vehicles are measured indirectly with utilized data can be collected from onboard CAN by using the digital tachograph developed for the purpose of support for eco-driving of commercial vehicles, in addition, the above results are compared with the results measured under quiescent conditions, also mentioned is its applicability for safe driving, eco-driving, and the control of moving states of the vehicles using ITS.

Keywords: Heavy Vehicles, Onboard Mass Unit, Green ITS, Safety Drive

1. Introduction

Because there is an obligation in Japan to install tachographs in logistics vehicles of 8 tons or greater, normal vehicles have analog tachographs installed as standard features. However, it is recognized that digital tachographs have the added value of fuel efficient driving and controlling vehicle motion, reducing risks while the vehicle is in operation. Thus, there are many cases where an additional digital tacograph is also installed.

Among digital tachographs, there are models which are attached using the CAN connector, allowing the acquisition of detailed engine management data. By using a model which can calculate the total weight of the relevant vehicle from its total drive force, the total weight of the vehicle during operating can be measured to secure safety while driving while contributing to Green ITS by driving at the appropriate weight, and can be used for vehicle weight management to reduce the effect on road structures.

This paper is a report of the results of an investigation of the basic performance of on board weight measurement devices using digital tachographs. In the experiment, total vehicle weight was measured on multiple transit routes and compared to the vehicle weight when completely stopped to examine the margin of error in measurement accuracy due to the difference in driving speed and environment.

2. Issues in traffic management for heavy vehicles

Currently, measures are required for Japanese road structures, such as bridges, that are rapidly aging. At the same time, the buildup of fatigue on roads due to the transit of some overweight vehicles, and heavy vehicles for which there is a low awareness of legal violations, is a factor in the aging and damage of road structures.

In Japan, a special vehicle transit permit program exists in which the road administrator gives permission for the transit of heavy vehicles that exceed a specified weight and size, in order to maintain road structure and prevent risks to traffic. However, over 30% of permitted vehicles exceed the limit in total weight (axle weight of 10 tons or total vehicle weight of 20 tons).

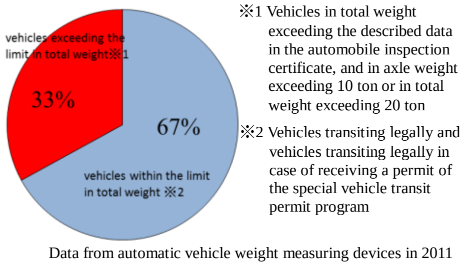

Figure 1. Appearance of violations about weights of heavy vehicles [1]

Further, accidents are being caused due to exceeding the total permitted weight.

3. Issues in methods for measuring vehicle weight

3.1 Conditions in Japan

Until now, direction and control of violating vehicles has been carried out regularly at control sites. In addition, the direction and control of regular offenders is being strengthened through the use of automatic vehicle weight measuring devices installed throughout the country.

However, for direction and control, it is necessary to direct heavy vehicles that are currently driving to enter direction and control sites, have them stop, and measure their weight, so there are significant time and space limits. Further, the installation of automatic vehicle weight measuring devices is expensive. Thus, one issue is that installed locations are few, and there are limited control locations.

3.2 Conditions outside Japan

In Australia, there is a limit to preparing fixed vehicle weight measuring devices because the size of the country is large. In light of that, vehicle weight is being monitored as part of the Intelligent Access Program (IAP).

3.2.1 IAP overview

The IAP (Intelligent Access Program) is a program that was developed in Australia as part of the online driving monitoring framework for commercial vehicles. In the program, location and other data obtained from one on board device is used by both the regulating body and the user (private business). Data is only sent to the regulating body when the vehicle deviates from the specified route, or if an on board weight meter (OBM) is installed, when the vehicle weight exceeds the limit. Further, data is provided to the private business for use in motion control and for daily work reports. A characteristic of this program is that a service provider exists for this program as a third party to collect the data, and accuracy is secured by a government authorization organization.

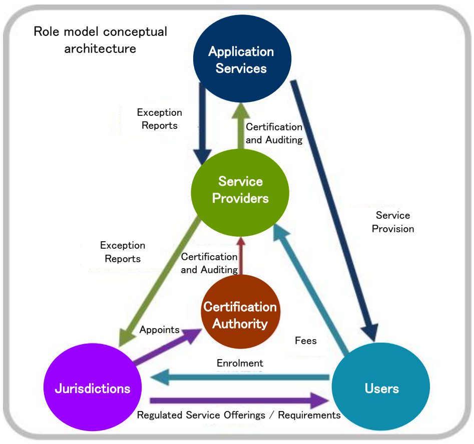

Figure 2. IAP architecture

4. System of the on board weight meter

4.1 EMS (Eco-drive Management System)

The EMS is an on board device that consolidates planned and continuous support for eco-driving, while providing objective evaluation of and guidance for driving conditions.

In terms of EMS devices, while details vary according to the characteristics of each on board device, the specific high-performing models of on board devices obtain, record, process, and judge vehicle data (such as fuel, CO_2, NOx, and PM emissions, speed, and driving operations) obtained from sensors installed in the engine and transmission in order to provide real time guidance for safe driving and improving fuel efficiency. Further, EMS devices also have a driving management system functioning as a digital tachograph, which is helpful in optimizing business. EMS is primarily spreading among automotive transport companies due to the expected effects of improved fuel efficiency and reduced CO_2 emissions, and because the national government is strengthening support for the project to spread the use of EMS (Eco-drive Management System).

The on board weight meter used in the investigation for this paper was originally developed as part of EMS. It was developed out of a requirement to calculate total vehicle weight because superimposed load was important for analyzing data from factors (driving environment, vehicle data, driving methods of the driver, etc.) effecting fuel efficiency for eco-driving support.

4.2. Overview of the on board weight meter

The following is the overview of the on board weight meter.


Figure 3. On board weight meter

- This is an eco-drive management system which can calculate total vehicle weight based on the superimposed weight that is calculated as part of that function.
- An online service is also provided allowing vehicle motion control in the office (though current commercial products do not have a system for sending the weight data)
- It is possible to display total vehicle weight on the on board monitor using the device's debug function
- No individual configuration is required, only connection to CAN
- In addition to total vehicle weight (kg), the data shown in Table 1, both CAN data and data calculated based on it, is collected every 0.1 seconds to support eco-driving.

Table 1. Main collected data from On board weight meter

Main collected data	Method of collecting and calculating
・Total vehicle weight (kg)	Shown in 4.3
・Degree of opening accelerator (%) ・Number of the engine rotations (rpm) ・Driving speed (km/h) ・Instantaneous fuel consumption（cc）	Collected from CAN
・Accumulated fuel consumption	Calculated by the accumulation of Instantaneous fuel consumption
・Instantaneous driving distance	Calculated by vehicle speed
・Accumulated driving distance	Calculated by the accumulation of Instantaneous driving distance

4.3 Logic for calculating total vehicle weight.

As shown in formula 1, the total vehicle weight (W) can be converted and calculated from the change in velocity during acceleration per time unit from vehicle axle motive power. In addition, factors used to calculate total vehicle weight (W) include variables such as air resistance, rolling resistance, and road grade, and highly precise total vehicle weight is possible by measuring those factors accurately.

Total vehicle weight is calculated using the above logic when weight measurement conditions are met. One of the example cases of the above is the time when a specified acceleration is exceeded between the stationary state and forward motion.

The calculation method of the gross weight of the vehicle (W)

(formula 1)

$$W = \frac{F - Rl - Wr \cdot \frac{V_2 - V_1}{\Delta t}}{g \cdot \mu r + \frac{V_2 - V_1}{\Delta t} + \sin\theta \cdot g}$$

$$F = \frac{Te \cdot it \cdot if \cdot \eta}{r} \qquad \mu r = \frac{1}{g} \cdot \frac{v1 - v2}{\Delta t}$$

F : The driving force (N)
RI : The air resistance
g : Acceleration of gravity
μr : The rolling resistance
V1 : The velocity at the acceleration (m/sec)
V2 : The velocity time after required time as t seconds (m/sec)
⊿t : The elapsed time from V1 to V2 (sec)
Wr : Equivalent weight of rotating parts

5. Experimental results from the driving test

5.1 Overview of the driving test

A heavy trunk with an on board weight meter was test driven on ① a general route of trunk roads in the greater Tokyo metropolitan area, as well as ② an expressway route of national and city expressways, and measurement results from the on board weight meter were collected.

5.1.1 Test vehicle and experimental methods

The heavy vehicle used for test driving had a weight of 10.5 tons and a length of 11.9 meters.

Steel sheets were placed on the truck bed to adjust the loaded state of the vehicle reach a total vehicle weight of 18.62 tons.

In addition to the on board weight meter, a GPS device and drive recorder were installed to obtain location data and drive video in addition to the weight.

Figure 4. External of the test vehicle

5.1.2 Test report

①Trunk roads route (Figure 5, Table 2)

- The circular route on trunk roads in the greater Tokyo metropolitan area was set to be run a total of four times, including two times in the clockwise direction and two times in the counter-clockwise direction.
- Route length: approximately 35 km

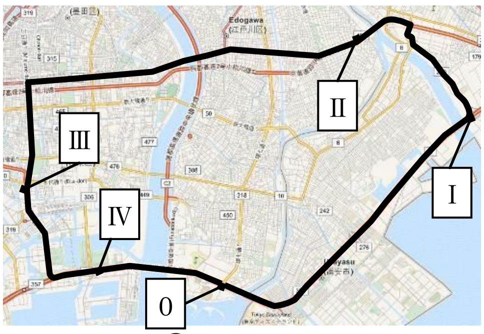

Figure 5. ①General (roads) route

Table 2. General (roads) route

Zone	Road name	Traffic condition, features of road architecture
0～Ⅰ	National route 357	Along the seaside. Traffic flow is good.
Ⅰ～Ⅱ	National route 298	Provisionally available because of construction work. Geometric curving is unfavorable.
Ⅱ～Ⅲ	• National route 14 • Primary regional roads	More signals stand and traffic is heavy, because the route runs through the middle area of the city.
Ⅲ～Ⅳ	Shuto Expressways※	Raised city expressways in parallel with the arterial roads, therefore On/Off ramp ways have steep pitches.
Ⅳ～0	National route 357	Along the seaside. Traffic flow is good.

※On the clockwise route, standard roads were used instead of the Shuto Expressway

② Expressway route (Figure 6, Table 3)

- A route was set using expressways within Tokyo and between cities
- One time in one direction(Route length: approximately 65km)

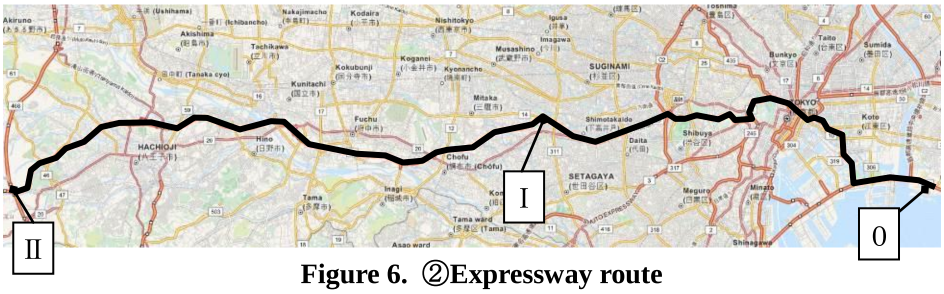

Figure 6. ②Expressway route

Table 3. Expressway route

Zone	Road name	Traffic condition, features of road architecture
0～Ⅰ	Shuto expressway	Inner-city-highway. Traffic is heavy. Geometric curving is unfavorable partially.
Ⅰ～Ⅱ	Chuo expressway	Inter-city-highway. Traffic flow is good.

5.2 Experimental results

①Trunk roads route

As a result of driving the 35 km route four times, it was found that the maximum margin of error for total weight measurement was 2.65%. (Table 4)

Table 4. The result of the measurement by the Onboard Mass Unit

①Trunk roads route	Item	Minimum	Maximum	Average
Anti-clock Rotation	Weight(t)	18.424	18.979	18.620
First try	Inaccuracy	-1.05%	1.93%	
Anti-clock Rotation	Weight(t)	18.424	19.114	18.752
Second try	Inaccuracy	-1.05%	2.65%	
Clock Rotation	Weight(t)	18.707	18.987	18.888
First try	Inaccuracy	0.47%	1.97%	
Clock Rotation	Weight(t)	18.672	18.859	18.795
Second try	Inaccuracy	0.28%	1.28%	

(The value of the weight under quiescent conditions as: 18.62t)

Further, changes in the measured value of total vehicle weight are shown in Figures 7 and 8. Total vehicle weight was measured according to changes in speed. Looking at the changes in total vehicle weight during the first and second runs of the counter-clockwise and clockwise runs, the same trend is not shown on each driving route from zones 0 to IV. The zone with the worst accuracy was on the second run between zones III and IV (Shuto Expressway) on the counter-clockwise run, but the results for the same zones on the first run were relatively close to the true value.

Figure 7. The result of the measurement by the Onboard Mass Unit in anti-clock rotation

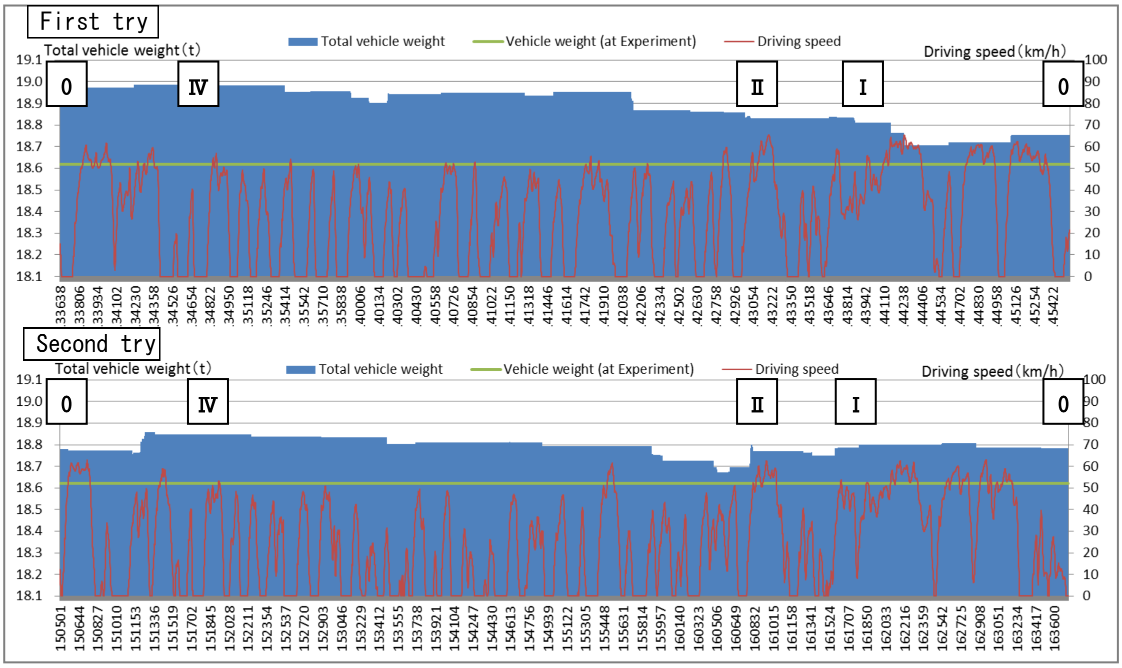

Figure 8. The result of the measurement by the Onboard Mass Unit in clock rotation rotation

② Expressway route

The margin of error for the ② expressway route was between 1.24% and 1.48%. (Table 5) Changes in the measured value of total vehicle weight are shown in Figure 9 and 10. There was little change in measured results compared to the ①Trunk roads route, and a stable measurement result was obtained irrespective of the road structure (road shape and grade) or driving speed in any zone. In other words, whereas on the general route, the conditions for weight measurement for the on board weight meter were met each time the vehicle stopped and restarted at an intersection stop light resulting in a measurement being taken again, on the ② expressway route, the weight measurement conditions were not met despite changes in speed, and measurements were not taken again, resulting in a stable measurement outcome.

Table 5. The result of the measurement in ②Expressway route

Zone	Item	Minimum	Maximum	Average
0～Ⅰ	Weight (t)	18.851	18.896	18.878
Shuto expressway	Inaccuracy	1.24%	1.48%	
Ⅰ～Ⅱ	Weight (t)	18.851	18.851	18.851
Chuo expressway	Inaccuracy	1.24%	1.24%	

(The value of the weight under quiescent conditions as: 18.62t)

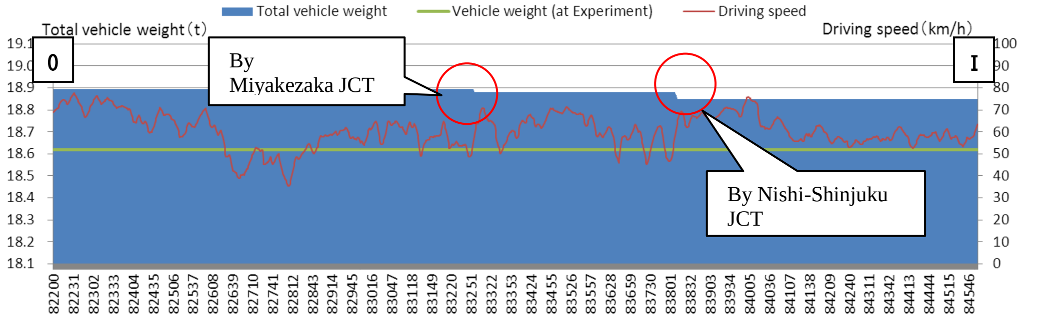

Figure 9. The result of the measurement by the Onboard Mass Unit in 0～Ⅰ Shuto expressway

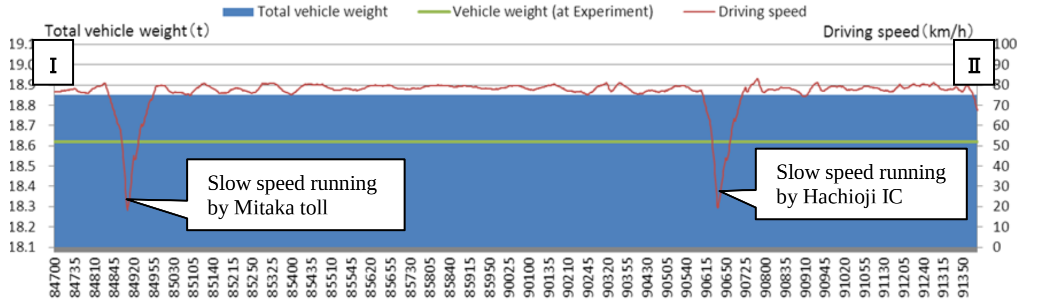

Figure 10. The result of the measurement by the Onboard Mass Unit in Ⅰ～Ⅱ Chuo expressway

Looking at the points were measurement results changed, specifically near the Miyakezaka JCT and Nishi-Shinjuku JCT, it can be suggested that acceleration when merging into main line traffic via the junctions caused the weight measurement conditions to me met and weight to be measured again.

6. Discussion of the results and issues

6.1. Discussion of the results

This experiment tested the measurement accuracy of total vehicle weight for heavy vehicles with an on board weight meter.

Measurement accuracy was measured on two routes, the ①Trunk roads route and ② expressway route. The margin of error for measurement was between -1.05% and 2.65% for the ①Trunk roads route, and 1.24% and 1.48% for the ② expressway route. Considering that the acceptable range for the automatic weight measuring device currently used for control is ±10% for vehicle weight, it was found that the accuracy of total vehicle weight monitoring was accurate.

It was also confirmed in this driving test that the accuracy did not drop during the complex traffic conditions with repeated slowing, accelerating, and stopping seen on the general route in the city center, and the expressway driving conditions on the expressway route. Further, it was confirmed that there was no significant drop in accuracy on ramps with sudden grades, or road structures with poor curves such as junctions, when entering the Shuto Expressway. Based on these results, it is believed that the measurement of total vehicle weight using an on board weight meter can be utilized under the driving conditions of logistics vehicles.

6.2 Issues

The on board weight meter used in this paper calculates total vehicle weight based on vehicle motive power. Weight cannot be measured unless the driving conditions for weight measurement are met, and thus total vehicle weight cannot be measured immediately after loading the vehicle. For that reason, an investigation of the measurement accuracy during acceleration immediately after loading is necessary. Further, the following issues remain regarding the monitoring of vehicle weight by the road administrator.

- The axle weight which has the greatest effect on road structures is not covered by measurement.
- While installation cost is about 180,000 Yen including the EMS function, there are inadequate incentives for businesses to install it.
- Methods for bureaucrats to collect vehicle weight measurement results
- There is no legal basis for the measurement results

7. Future outlook

7.1 Driving route support based on vehicle weight that operates in tandem with the car navigation system

Currently, the on board weight meter calculates total vehicle weight to support eco-driving to improve fuel efficiency. As there is no demand for the total vehicle weight data while driving among cargo owners and drivers, aggressive use of the data is not seen.

At the same time, logistics vehicles transit routes permitted after requesting a permitted route based on total vehicle weight under the current special vehicle transit permit program. However, the loaded cargo is not necessarily a set weight, and the total vehicle weight changes when cargo is added or unloaded en route. For that reason, if it were possible to guide drivers to a route appropriate for the current total weight while driving, through coordination between the car navigation system and permitted route, this would lead to efficient transit route selection which could contribute to the maintenance of road structures and the reduction of CO_2 emissions.

7.2 Utilization in support for safe driving based on knowledge of the center of gravity

One issue for container vehicles is that accidents may occur more easily under excessive loading and unbalanced loads. Particularly, one characteristic of international maritime containers is that the driver cannot check the state of cargo in the container.

However, support for safe driving can be expected for vehicles for which the cargo cannot be checked, such as international maritime containers, because on board weight meters calculate the center of gravity of vehicle weight while driving (front or back, left or right).

As shown above, if the merits to installing on board weight meters increase in the future, EMS that contain combined functions for the calculation of total vehicle weight will spread, and an argument for making EMS installation mandatory can be promoted to enable drive monitoring of heavy vehicles for the maintenance of road structures and the safe driving of heavy vehicles.

8. ACKNOWLEDGMENT

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9. REFERENCES

[1] “Strengthening of an efficient physical distribution network” in Proceedings of The 42nd basic policy sectional meeting (Japan,2013)