THE OVERLOADED VEHICLE CRACKDOWN EFFORT BY HIGH-PRECISION AUTOMATIC AXLE WEIGHING SYSTEM IN HANSHIN EXPRESSWAY

Koichi-Katsuoka, Akira-Furuta, Koichi-Horikoshi
Facility maintenance Group, Osaka Business and Maintenance Department
Hanshin Expressway Company Limited,Japan
koichi-katsuoka@hanshin-exp.co.jp, akira-furuta@hanshin-exp.co.jp,
koichi-horikoshi@hanshin-exp.co.jp

ABSTRACT

The Hanshin Expressway has a network of 242 kilometers in the Kansai urban area (Osaka, Kobe, and Kyoto) of Japan, and contributes to its economy and life.

Our most essential tasks are prevention of extensive damage to road structures, mitigation of noise and vibration caused by the vehicles such as overloaded trucks, and to prevent traffic accidents. Therefore, we have set up an automatic axle weighing system on the expressway toll plazas, and have been cracking down on the overloaded vehicles. The system can measure vehicle's static axle loads while they pass through toll plazas at the maximum speed 20 kilometers per hour.

However, the system has to measure the loads from running vehicles at about 40 kilometers per hour, because ETC, or Electronic Toll Collection System has been installed in toll plazas, and vehicle passes through without decelerating. To solve this problem, the high-precision automatic axle weighing system has been developed and installed in 119 toll plazas with ETC system.

This paper explains the outline of the high-precision automatic axle weighing System, and the results of performance tests. In addition, the crackdown effort on overloaded vehicles is introduced.

1. INTRODUCTION

In Japan, in order to prevent road damage and to secure a safe drive condition, maximum vehicle height and maximum vehicle weight are limited under the Article 3 of the Vehicles Regulations Order. The research of Hanshin Expressway Company Limited about steel plate deck's fatigue damage in 2007, Overloaded vehicles lead about 30% damage of the steel plate deck, even if overloaded vehicles occupy within only 0.3%~0.5% of total traffic. By the crackdown on these overloaded vehicles, road structure's fatigue life can be prolonged 30%. Moreover, these overloaded vehicles have harmful effects, such as the noise and the vibration to the residential areas, and the traffic accidents.

Thus, the crackdown on overloaded vehicles is effective for risk managements as follows.

・Reduction of noise and vibration risk for life environment and society.

・Reduction of traffic accident victims and incident congestion risk.

・To prevent the structure damage, and lengthen structure life. And to suppresses rising repair cost.

Hanshin Expressway Company Limited has set up automatic axle weighing system on the expressway toll plazas to measure the vehicle’s static loads, and has been cracking down on the overloaded vehicles under the Act. Table1-1 shows limitations of vehicle size and weight in Japan. To conduct crackdown as a legal act, the system’s measurement accuracy is important. It is because there are some court cases with vehicle owners who deny their offending and we have to prove our allegation by a preponderance of evidence.

However, the system has to measure the static load from the running vehicles at about 40 kilometers per hour, because many vehicles have started to pass the toll plazas without decelerating by using ETC, or Electronic Toll Collection System installed in the toll plazas. Moreover, ETC-bar’s switching timing changed vehicle’s movement and made vehicle’s vibration more complex.

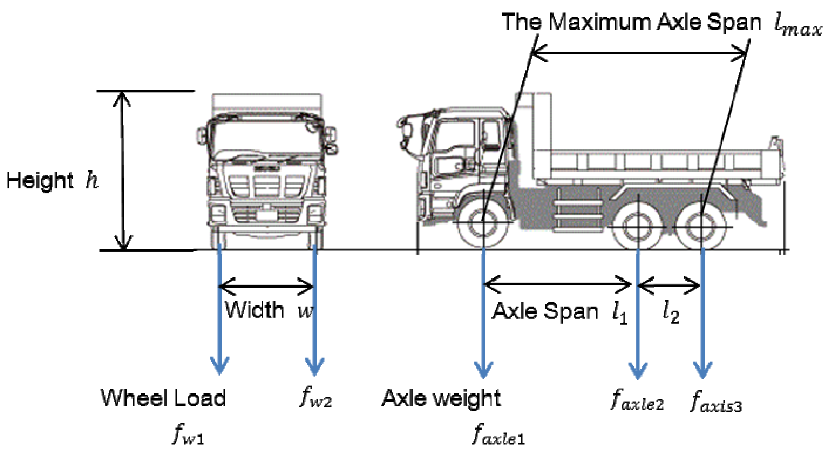
Therefore, Hanshin Expressway Company Limited developed the more precise system from the conventional automatic axle weighing system after the performance tests. Currently, 119 systems have been set up and operated on the Hanshin Expressway network. Moreover, as well as the improvement of measurement accuracy, we have considered the shortening of the duration to identify vehicle owners is important for risks noted above. Therefore, we used ETC photo data for new system and automated crackdown. This made it possible to send warning letters to the vehicle owners immediately.

In addition, we conduct crackdowns at the toll plazas where the number of overload vehicles is especially large.

Table1-1, Limit Value of Vehicles in Japan

Specifications		Limit Value (Maximum Limit)
Width		2.5m
Length		12.0m
Height		3.8m
Weight	Total Weight	20.0t
	Axle Weight	*10.0t
	Wheel Load	5.0t
Minimum Turning Circle		12.0t

* If the span of two axles is close, their total axle weights is limited.



Hanshin expressway allows total weight up to the 27tons due to its maximum axle span. Table1-2 shows the limiting value due to its maximum axle span in Hanshin expressways.

Table1-2, Weight Limit due to Maximum Axle Span

Maximum Axle Span l_{max}	Total Weight
8.0m~9.0m	25t
~10.0m	26t
Over 10.0m	27t

2. OUTLINE OF THE HIGH-PRECISION AUTOMATIC AXLE WEIGHING SYSTEM

2.1. Placement of the machinery

High-precision automatic axle weighing system is composed of plate type sensor, bar shaped sensors, vehicle detecting instruments, processing units, and warning plate.

This new system uses photo data of the ETC system instead of setting photo booth. Figure2-1 shows the machinery placement of the system.

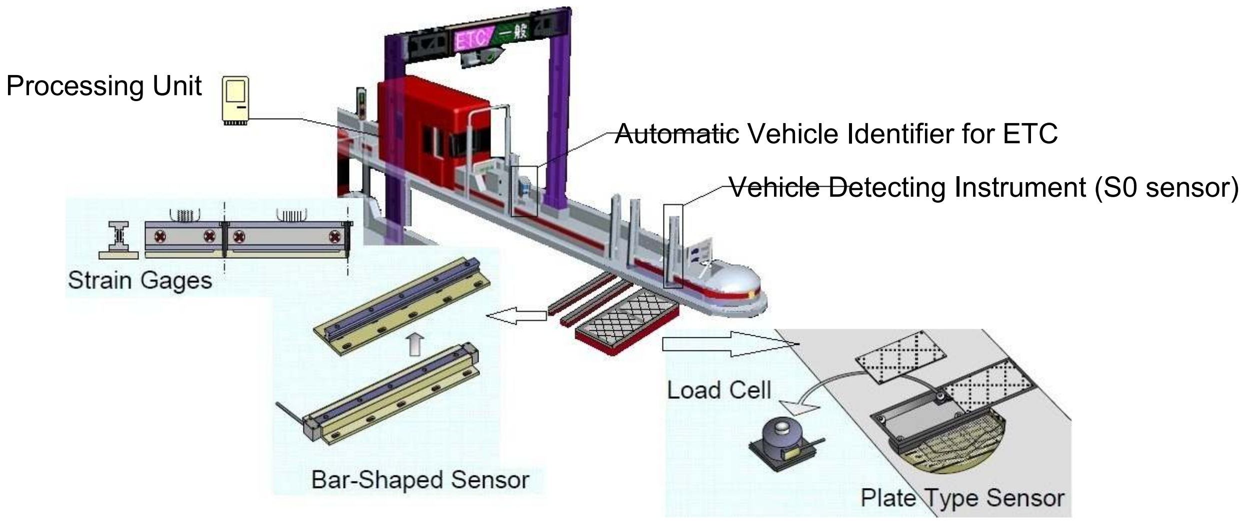


Figure2-1 Placement of the Machinery [1]
(High-precision Automatic Axle Weighing System)

Table2-1 shows the comparison of the new system with the conventional system. One of the biggest differences is the two bar shaped sensors. By using these sensors, the system can get more number of the sensor data, and can measure the speed of the vehicles.

The calculation process is changed due to the vehicle's speed, and it becomes possible to measure more accurate vehicle's axle weight. Moreover, the measurement capacity is improved from 20 kilometers per hour to 40 kilometers per hour.

The other difference is the vehicle detecting instrument. These make it possible to sort axle into each vehicle and to measure the vehicle's total weight from the axle weights

Table2-1, Comparison of the New System with the Conventional System

Specifications	Conventional System	New System
Capacity of the Processing Unit	1 lane / piece	(maximum) 2lanes / piece
Measurement Capacity of the System	0~20km/h	0~40km/h
Target Precision	±5%FS	±5%FS
Measuring Contents	Axle Weight	Speed, Axle Weight, Total Weight
Component of the Sensors	One Plate Type Sensor	One Plate Type Sensor Two Bar Shaped Sensors
Photographic Equipment	Film type	Digital type
Vehicle Detecting Instrument	—	S0 sensor S11,S11 sensor (for ETC)

2.2. Measurement method of the High-precision Automatic Axle Weighing System

Axle weight of running vehicle is unstable and its data has the waveform. Automatic axle weighing system gets the vehicle's static load from the waveform data by using a particular calculation process.

Figure2-2 shows an example of the calculation process. When the vehicle runs at high speed, the number of the sensor-acquired information becomes too small to measure axle weight with a high degree of accuracy. The new system uses additional axle weight data from bar shaped sensor 1 and 2 to fill the shortage of the data, and vehicles static load is measured by wave analysis.

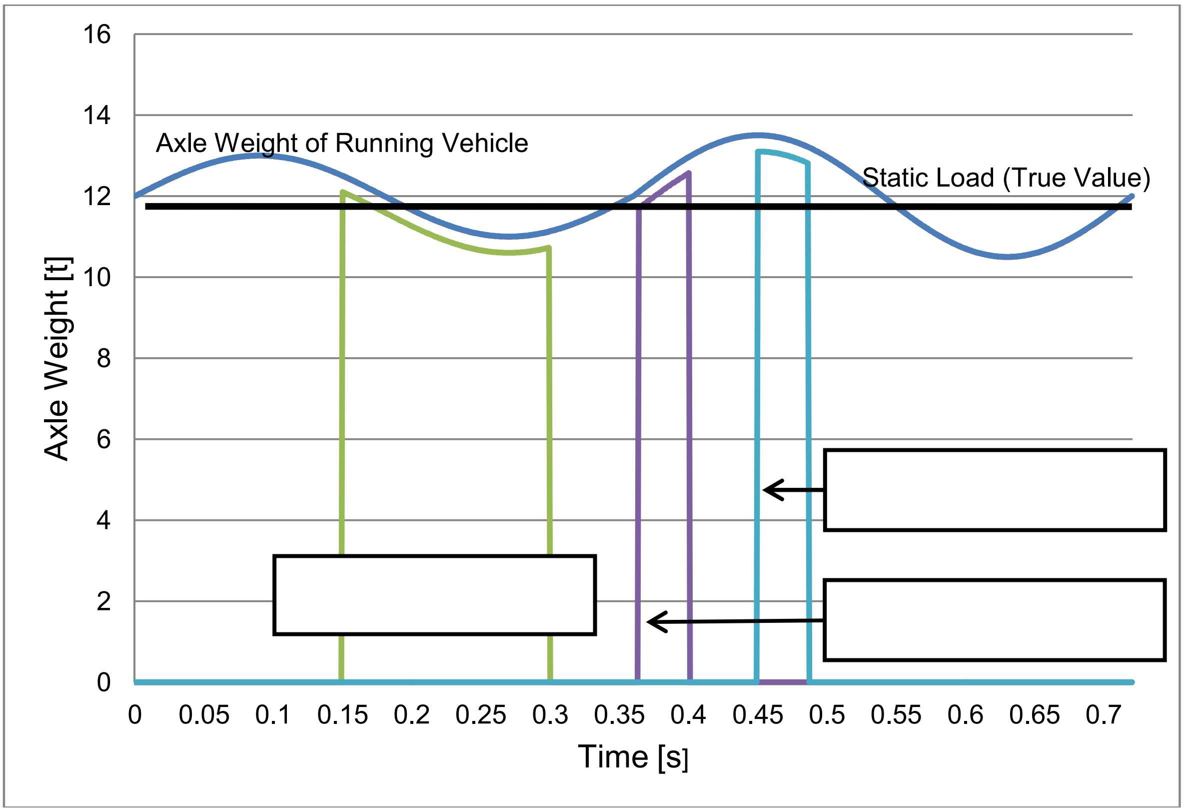


Figure2-2, Example of the Calculation Process

3. RUNNING TESTS OF HIGH PRECISION AXLE WEIGHING SYSTEM

3.1. Outline of the Tests

In order to install new weighing system on toll plazas, it is necessary confirm that new system has sufficient measurement accuracy and reliability. Therefore, we conducted running tests on the test track to examine the measurement precision of the high precision axle weighing system before practical use.

We examined the follow characteristics by running tests.

・Relationship between the vehicle's speed and the measurement error.
・Measurement accuracy's differences caused by the types of vehicles.
・Relationship between the road surface condition and the measurement accuracy.
・Relationship between the acceleration(deceleration) and the measurement accuracy.

And Figure 3-1 shows the brief overview of running tests in Koshienhama of Hanshin Expressway.

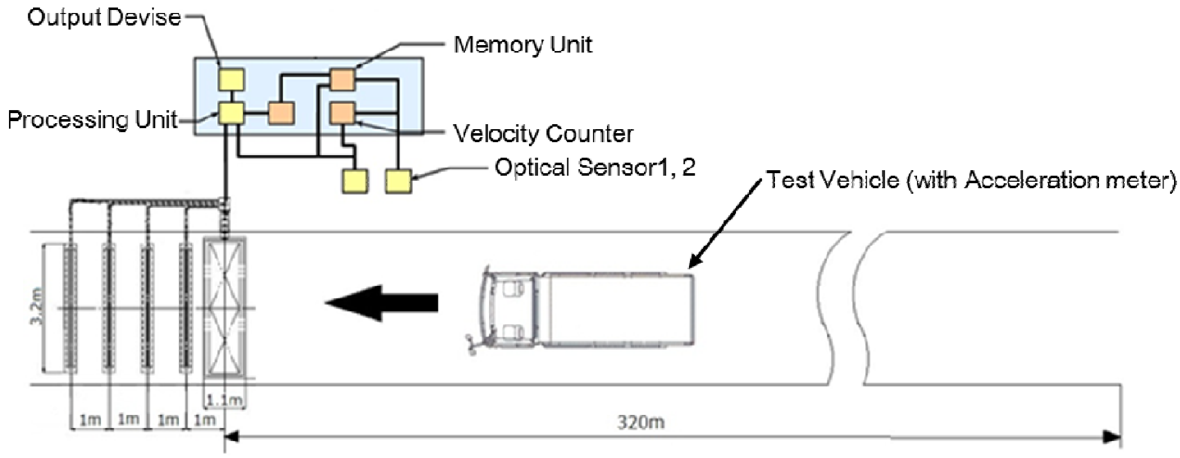


Figure3-1, Overview of the Running Test

Running speed is set from 5 kilometers per hour to 80 kilometers per hour at 5kilometers per hour intervals as a target value. The actual speed is evaluated from running time and distance between two optical sensors as shown in Figure 3-1.

The test vehicles are the three-axle dump truck shown in Figure 3-2 and the four-axle semitrailer truck shown in Figure 3-3. Acceleration meters are installed in each vehicle. Some weights are set on each vehicle to adjust its weight.

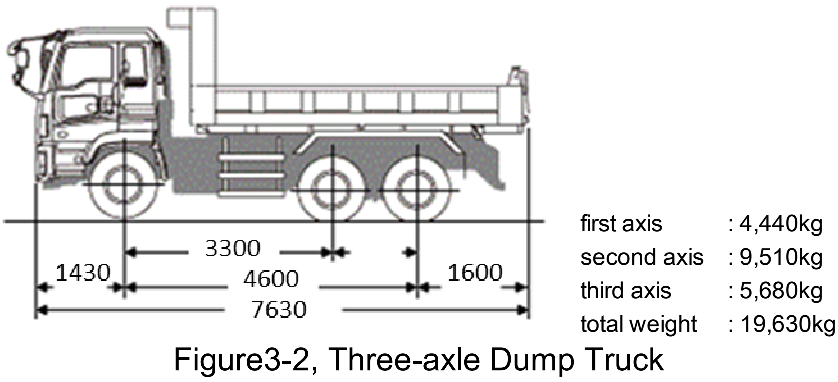


Figure3-2, Three-axle Dump Truck

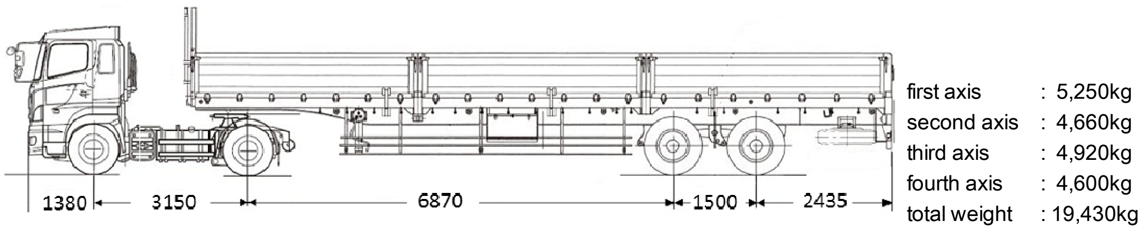


Figure3-3, Four-axle Semitrailer Truck

The measurement is basically conducted with a system composed of a plate type sensor and two bar-shaped sensors. As additional tests, three or four bar-shaped sensors in the system are utilized.

3.2. Test Results

New system's accuracy is evaluated by the measurement's error rate from 20 tons (20t%FS method). It is because overloaded vehicle crackdown needs the accuracy in the range of heavy weight.

3.2.1 Accuracy Tests on the flat test track

Figure 3-4 shows the test results of the three-axle dump truck on the flat test track. The results show that the error rate stays within ±2.5%FS under 40 kilometers per hour. However, at faster than 70 kilometers per hour, the accuracy becomes worse gradually. -5.5%FS(at 80km/h, 1st axle), +3.0%FS(at 70km/h, 2nd axle), and +4.5%FS(at 80km/h, 3rd axle) were measured on the each axle. There is a tendency that measured 1st axle weight is lighter than its actual weight and measured 3rd axle is heavier.

Figure 3-5 shows the test results of four-axle semitrailer truck. The error rate also stays within ±2.5%FS under 40 kilometers per hour. -4.5%FS(at 70km/h, 1st axle), +2.5%FS(at 70 and 80km/h, 2nd axle), -2.5%FS(at 30 and 60km/h, 3rd axle), and -2.0%FS(at 20km/h, 4th axle) are measured on each axle. There is a tendency that the measured 1st axle weight is lighter and measured 2nd axle weight is heavier with the growth of the speed.

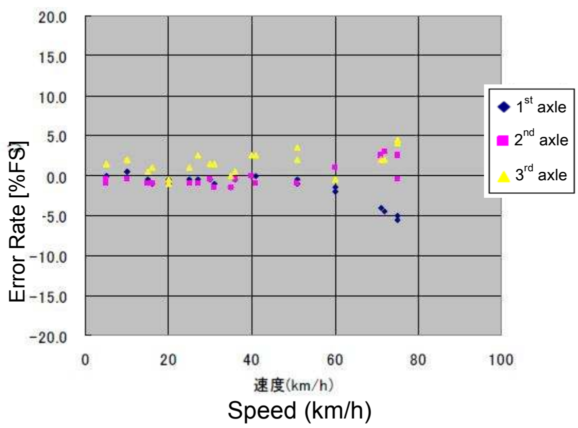


Figure3-4, Results of the Three-axle Dump Truck (on the flat test track)

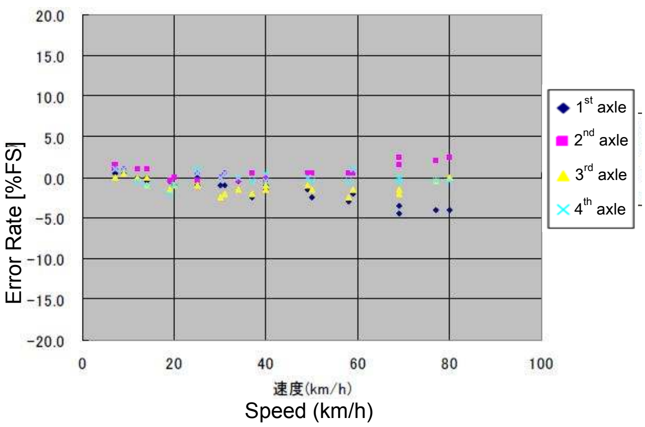


Figure3-5, Results of the Four-Axle Semitrailer Truck (on the flat test track)

Figure 3-6 and figure 3-7 shows each vehicle's results of the Conventional Axle Weighing System on the flat test track. It should be noted that the new system's accuracy is better than that of conventional system.

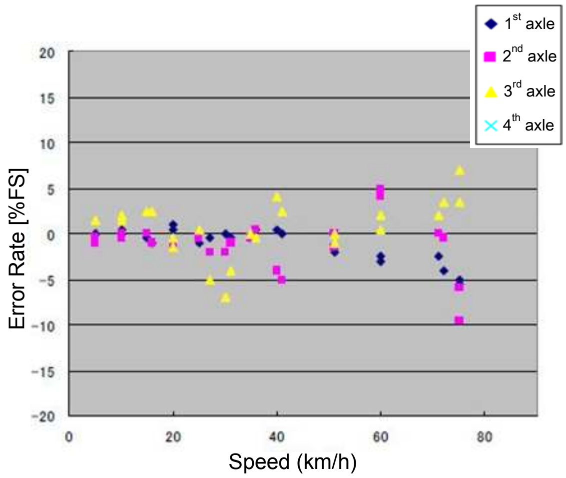


Figure3-6, Results of the Conventional Axle Weighing System (Three-axle Dump Truck On the flat test track)

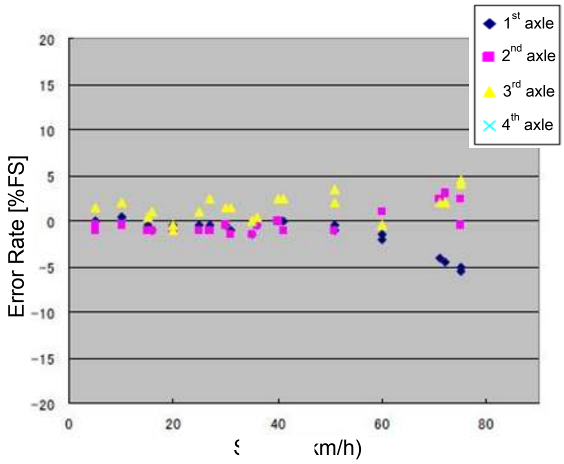


Figure3-7, Results of the Conventional Axle Weighing System (Four-Axle Semitrailer Truck On the flat test track)

3.2.2 *Accuracy Tests on uneven test track*

The same tests are conducted on the uneven road surface. Mock bumps made by 3millimetres thickness rubber plates are set near the system as shown in figure3-7.

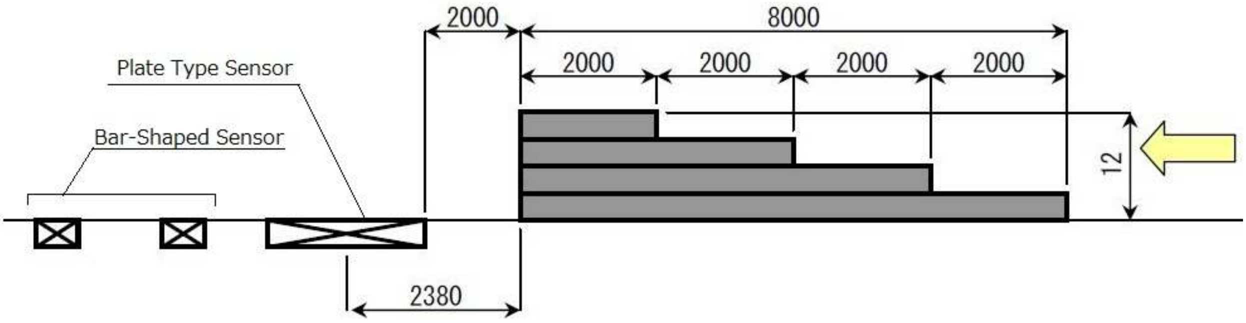


Figure3-8, Uneven Test Track

Figure3-9 shows the measurement results of the three-axle dump truck. The error rate stays within ±2.5%FS under 30 kilometers per hour, and it is said that the new system can ensure the measurement accuracy in some degree even on the uneven road surface. However, at the range of over 40 kilometers per hour, the accuracy becomes worse. In specific, the error at 40km/h approached +9.0%FS(at the 3rd axle), and the maximum error was +14.0%FS(at 80km/h, 3rd axle).

Figure3-10 shows the result of the four-axle semitrailer truck. Each maximum error were -3.0%FS(at 70km/h, 1st axle), +3.5%FS(at 70km/h, 2nd axle), +4.0%FS(at 70km/h, 3rd axle),and -3.0%FS(at 10km/h, 4th axle), respectively. The error rate stays within -3.0%FS～+1.5%FS under 40 kilometers per hour, and it also stays within -3.0%FS～4.0%FS under 70 kilometers per hour.

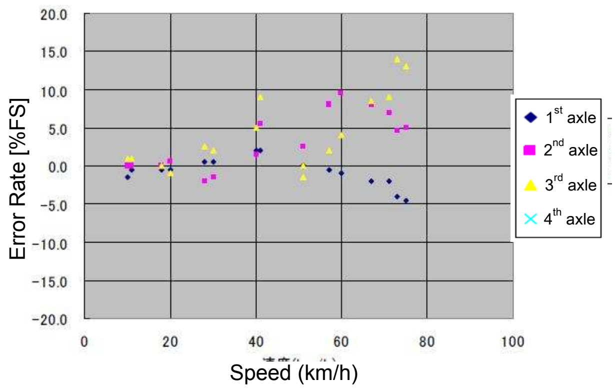


Figure3-9, Results of the Three-axle Dump Truck
(on the uneven test track)

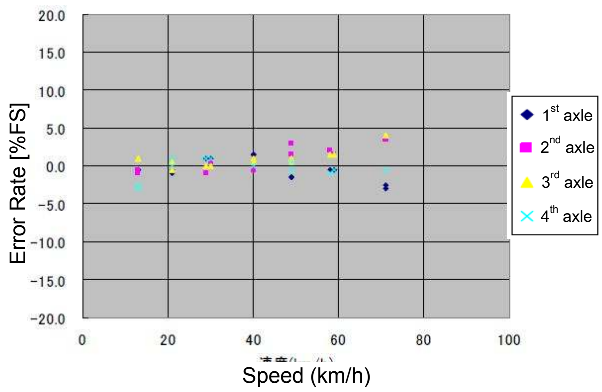


Figure3-10, Results of the Four-Axle Semitrailer Truck
(on the uneven test track)

3.2.3 Accuracy Tests in Acceleration (Deceleration) State

Moreover, accuracy tests are conducted in the case of acceleration state and deceleration state. Figure3-11 shows a brief overview of the test in acceleration state. Figure3-12 shows a brief overview of the test in declaration state. Table3-1 shows the vehicle's actual speed in the test.

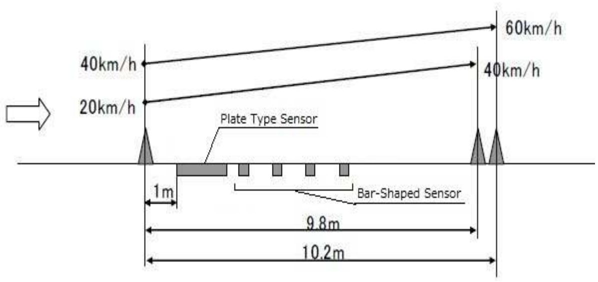


Figure3-11, Test in Acceleration State

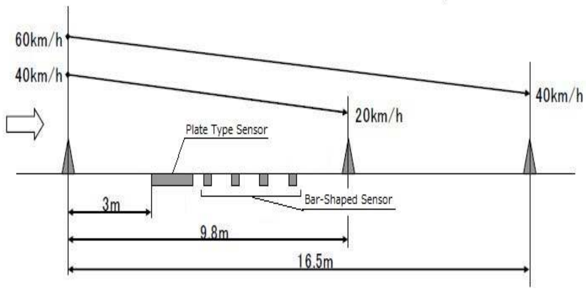


Figure3-12, Test in Declaration State

Table3-1, Vehicle's Actual Speed and its change in the Test

The state	Speed / Round	Target Speed [km/h]			
		20→40	40→60	40→20	60→40
		Measured Speed (1st axle, 2nd axle, 3rd axle, 4th axle) [km/h]			
Acceleration	1st Round	24, 26, 30, 31	41, 41, 43, 43	-	-
	2nd Round	26, 29, 32, 33	42, 43, 44, 44	-	-
	3rd Round	26, 29, 32, 33	42, 43, 44, 45	-	-
Deceleration	1st Round	-	-	35, 33, 29, 29	54, 52, 49, 47
	2nd Round	-	-	35, 32, 29, 28	55, 54, 51, 51
	3rd Round	-	-	36, 33, 28, 27	54, 52, 50, 50

Figure3-13 shows the result of the tests in acceleration state. There is a similar tendency between the track part and the trailer part. As for the track part, measured 1st axle weight is lighter than actual weight, and measured 2nd axle weight is heavier. As for the trailer part, measured 3rd axle weight is light, and measured 4th axle weight is heavy.

On the other hand, figure3-14 shows the result of the experiment in declaration state. As for the track part, captured 1^{st} axle weight is heavier than actual weight. And captured 2^{nd} axle weight is vice versa in the acceleration state.

However, as for the trailer part, the result was similar to that in the acceleration state.

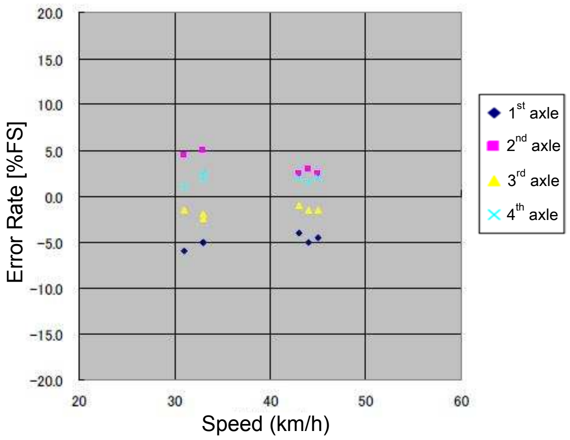


Figure3-13, Results of Tests in Acceleration State

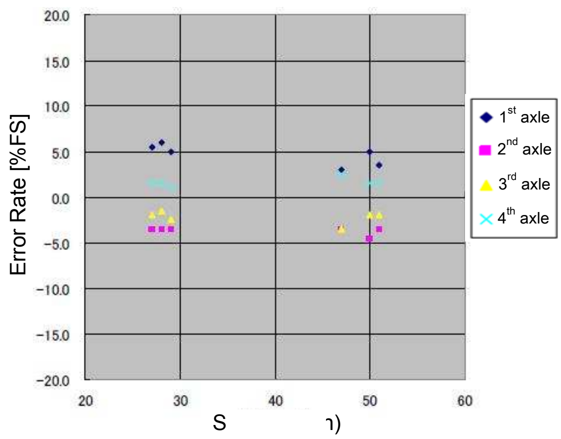


Figure3-14, Results of Tests in Declaration State

3.2.4 Accuracy Tests in Case of Changing Bar Shaped Sensor's Number.

In this test, the number and the position of bar shaped sensors are changed in order to examine the difference of the measurement accuracy caused by the number of sensors. Test specification is shown in Table 3-2 and Figure 3-15.

Table3-2, Pattern of the bar shaped sensor's number

Case No.	Plate Type Sensor	Bar Shaped Sensor 1	Bar Shaped Sensor 2	Bar Shaped Sensor 3	Bar Shaped Sensor 4
Case 1	○	○			
Case 2	○	○	○		
Case 3	○	○	○	○	
Case 4	○	○	○	○	○

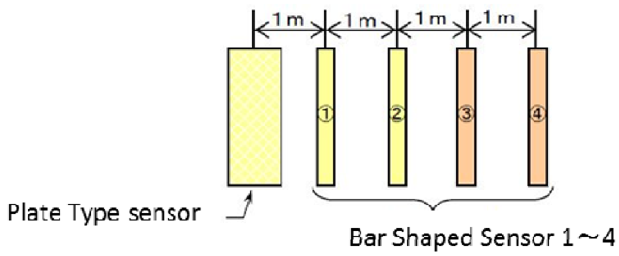


Figure3-16 shows the relationship between the measurement accuracy and the number of bar shaped sensors. The more bar shaped sensors are placed, the less error rate become and approach to 0%FS. The measurement accuracy becomes better especially under 40 kilometers per hour.

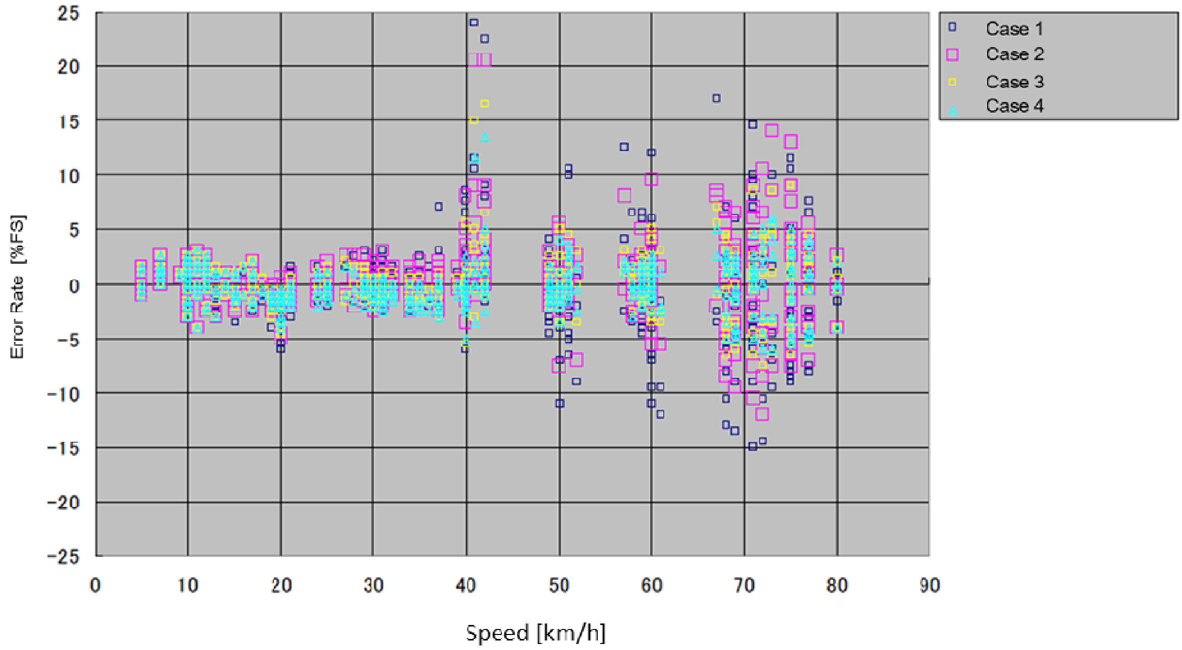


Figure3-16, Relationship between the Measurement Accuracy and the Number of Bar Shaped Sensors

3.2.5 Consideration of Accuracy Tests

The Measurement accuracy on the flat track stayed within ±5%, even if the speed was 40 kilometers per hour. But, it became worse over 30 kilometers per hour on the uneven track. It is said that uneven road surface condition has negative influence on the measurement accuracy. Therefore we decided to measure longitudinal variation of road surface by using surface profile measurement device before the sensors are set. Figure 3-17, 3-18 show the road surface profile measure and that data.

According to the tests in the acceleration (or deceleration) state, the target accuracy (±5%FS) was not achieved. And we decided to add the function which changes the calculation process only when there is a vehicle accelerates (or decelerates) rapidly at unexpected level. However, there is almost no vehicle which accelerates (or decelerates) at the same level like these tests.

The most vehicles passing toll plaza run under 40 kilometers per hour. Therefore, Hanshin Expressway decided to place a plate type sensor and two bar shaped sensors as default, and to add the bar shaped sensors if there is a toll plaza which vehicles pass faster than 40 kilometers per hour.

Figure 3-17　Road Surface Profile Measure

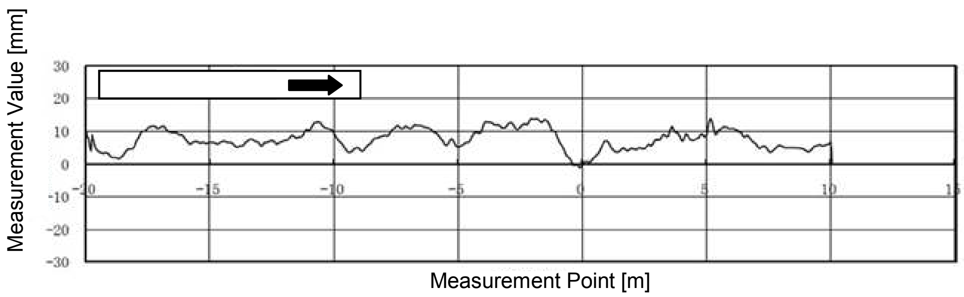


Figure 3-18 Road Surface Profile Data

4. OVERLOADED VEHICLE CRACKDOWN EFFORT

4.1. Establishment of the Crackdown in Hanshin Expressway

Hanshin Expressway Company Limited sets up the specialized department for the crackdown in Osaka and Kobe regions. It is based on the Act on Special Measures concerning Road Construction and Improvement, and these departments have been cracking down on the over loaded vehicle and warning its owner.

As the way of the crackdown, following countermeasures are conducted in parallel.
・The remote crackdown by using the High-precision Automatic Axle Weighing System.
・The crackdown on the vehicles at the toll plazas.

4.2. Remote Crackdowns by Using the High-Precision Automatic Axle Weighing System

Fig4-1 shows the workflow of the remote crackdowns. When the high-precision automatic axle weighing system finds out overloaded vehicles, the vehicle's axle weight data are combined with the digital image taken by the Automatic Vehicle Identifier for ETC system. Then, the data are sent to the monitoring center as the illegally passed vehicle's data. Hanshin Expressway Company Limited has been accumulating the database of the illegally passed vehicle's information. The records of illegal acts are checked from the database. If it is verified as vicious, a warning letter is sent to the driver or the owner. If the special warning is needed, the list is sent to the police.

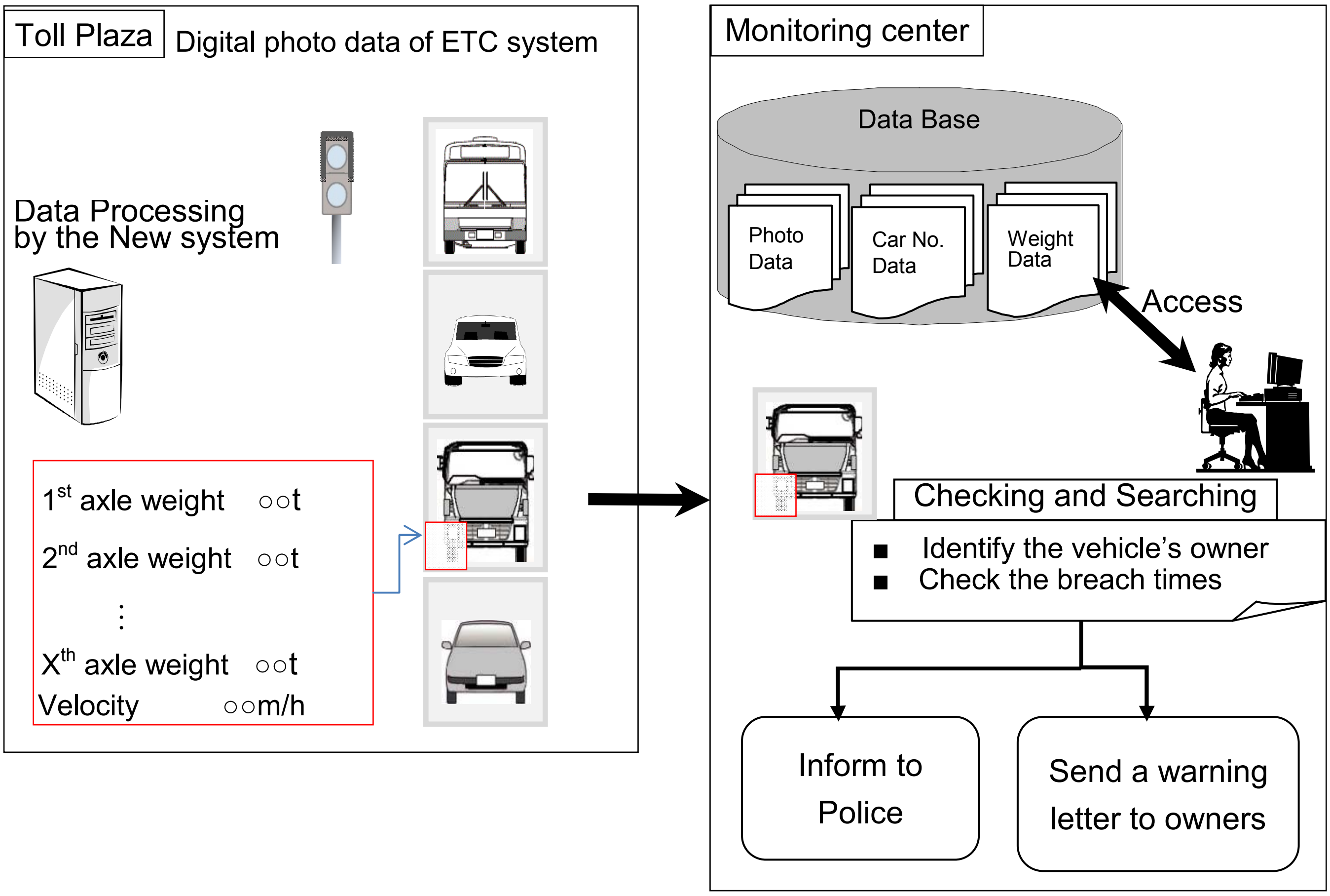


Figure4-1, Workflow of the Remote Crackdown

4.3. The Crackdowns on Vehicles at the Toll Plazas

Hanshin Expressway Company Limited conducts not only the remote crackdowns but also the crackdowns at the toll plazas. It is conducted for the vehicles with which the new system cannot deal, such as tracks without its license plate or without its ETC system.

Moreover, there are vehicles violating the other limitation, such as height, length, width as stipulated in the Vehicles Regulations Order. To reduce these cases, the crackdown at the toll plazas is needed, and the crackdown activity with police is taken place if necessary. The number of the crackdown at the toll plaza is 2500~3000 per a year. And the number of the warning is 1000~1500 per a year.

Figure4-2 shows a case example of the crackdown at a main lane plaza. In this case, we block off the No.5 lane and make the crackdown space at the back of the toll plaza. When the overloaded vehicles run into the toll plaza, they are directed to the crackdown space. Their static loads are measured by the portable type axle weighing scale, and then the drivers are warned.

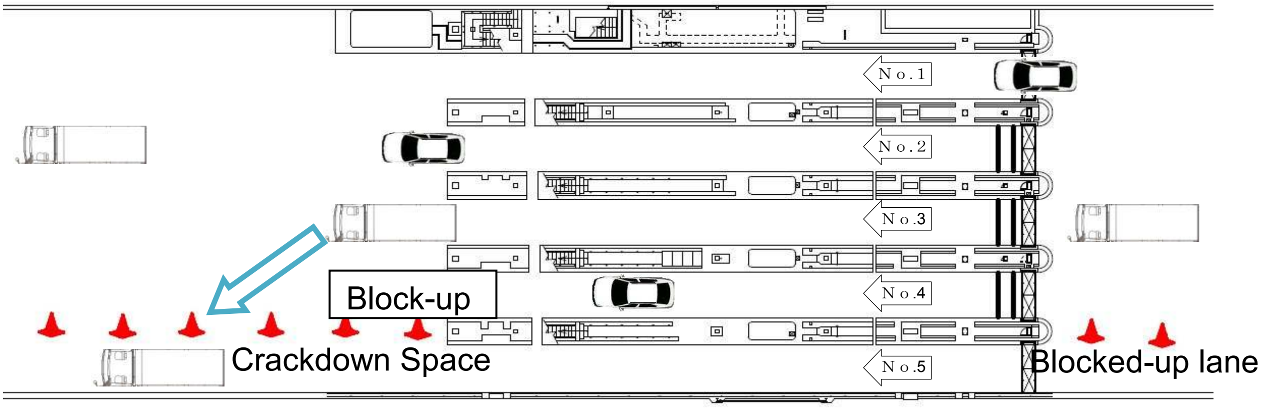


Figure4-2, Case Example of the Crackdown at the Toll Plaza

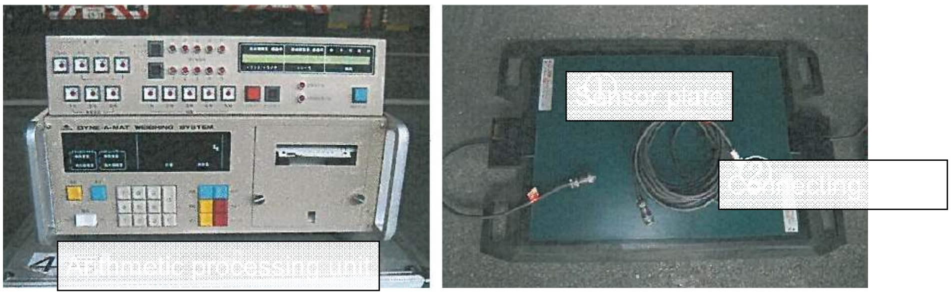


Figure4-3, Portable Type Axle Weighing Scale

5. FUTURE EFFORT

Several years have passed since the high-precision automatic axle weighing system has been in practical use, and it will be set on all planed lanes (122 lanes) next year.

Hanshin Expressway Company Limited sends the overloaded vehicle's data to police with Ministry of Land, Infrastructure, Transport and Tourism managing national routes (MLIT). We enhance crackdown activity with such a party involved.

As an activity for the prevention of recurrence and the compliance with a regulation, we held the lecture class for ''the risk of the overload'' or ''the vehicle limitation based on Road Act'' with the corporation of police and MLIT. We will continue this effort.

In addition to the crackdown by using high-precision automatic axle weighing system, we are planning to exam the system which measures vehicle's height and length for the crackdown to secure a safe drive environment

REFERENCES

1. Someya,k.,Okuda,H.,Shindo,T.,Maeda,Y.(2008),"DEVELOPMENT OF AXLE LOAD WEIGHING SYSTEM FOR EXPRESSWAYS",International Heavy Vehicle Conference HVParis2008 (HVTT10-ICWIM5),Paris,May19-22,Eds.B.Jacob,E.J.OBrien,A.OConnor,M.Bouteldja,LCPC Publications,HVParis2008-ICWIM5,ISTE,London,pp.261-267.