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Practices of using weigh-in-motion technology for truck weight regulation in China

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ABSTRACT

Trucks exceeding legal axle and gross vehicle weight limits can bring severe damage to infrastructure and increase the risk of traffic crashes. It is therefore important to ensure that freight carriers comply with weight regulations. This paper provides a comprehensive review of how weigh-in-motion (WIM) technology has been used to improve the truck weight regulation in China. In particular, a toll-by-weight method is introduced for trucks using toll roads. Compared to the conventional vehicle class based toll structure, the toll-by-weight method establishes a fair fee structure that prevents overloaded trucks from taking advantage of non-overloaded trucks. It also allows freight carriers the flexibility of moderate overloading by paying higher toll rates. This paper further proposes a mechanism of integrating toll-by-weight with effective weight enforcement for truck weight regulations. It encourages overloaded trucks to use toll roads instead of vulnerable non-toll roads, and helps to generate additional much needed revenues by local governments for highway construction, maintenance, and truck weight enforcement. In addition, technical and managerial problems affecting the applications of WIM are pointed out in this paper. Finally, perspectives on future WIM development and adaptions of other advanced technologies for truck weight regulations are presented.

1. Introduction

Weigh-in-motion (WIM) is a popular and efficient technology that can measure a vehicle's weight while it is traveling at normal or reduced speeds. It has been around for several decades and has become an integral part of highway management. There are numerous applications around the world using WIM for truck weight regulations such as determining truck toll rates and truck weight enforcement. WIM systems typically consist of sensors installed in the pavement upstream of weigh stations. These weigh stations along highways are also equipped with static scales as well as parking facilities for truck weight enforcement (Regan et al., 2006). There are many commercial WIM systems available and most of them can generate reasonably accurate results. These WIM systems are used mainly for identifying potentially overloaded trucks. The collected data can also be used for surveying or vehicle re-identification purposes.

In Netherlands, France, Sweden, Japan, and other countries, systems consisting of WIM and video cameras have been implemented to capture and continuously monitor overloaded trucks. For the captured trucks, a warning usually is sent to the registered owners. These WIM systems, in general, have been proven to be very effective in reducing truck overloading (Jacob and Loo, 2008; Honefanger et al., 2007). The situation in China, however, is quite different. The transportation infrastructure in China has undergone a fundamental transformation in the past 20 years with the construction of an almost completely new highway system. The total length of the newly constructed national highways is more than 74,100 km. By the end of 2010, over 3.5 million kilometers of rural highways have been either constructed or upgraded (Statistical Bulletin, 2011). In China, not all overloaded trucks are pulled off highways immediately. Instead, some of them are still allowed to use the highways by paying an overloading fee. To monitor truck weights and charge appropriate overloading fees, China has been using the bending plate WIM technology on toll roads since 2001 (Randy and Bushman, 2008). So far, thousands of WIM systems have been installed for collecting overloading fees. In addition, more than 700 WIM systems have been installed strictly for truck weight enforcement purposes. It is anticipated that more and improved WIM systems will be implemented in the near future to better manage and operate the highway systems in China.

Although WIM has been used for over 10 years in China to ensure the compliance of truck weight regulations, the past experience shows that WIM technology cannot effectively reduce the number of overloaded trucks without appropriate regulatory policies, and there

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are still issues and challenges that need to be addressed. It is necessary to conduct a review of existing applications of WIM systems for truck weight regulations, identify best practices, and share successful experience. In this paper, we introduce two types of truck weight regulation method in China. One is *toll-by-weight*, which is widely adopted by highway operating agencies. The other is *truck weight enforcement*, which is jointly enforced by highway administrations and traffic police. The characteristics of WIMs are introduced first and the practices of using WIM technology for toll-by-weight and truck weight enforcement in China are presented. The effects and consequences of each truck weight regulation method are also analyzed and summarized. Furthermore, we investigate the mechanism of systematically implementing truck weight regulations and explain why the toll-by-weight method has become so popular in China. Finally, we discuss the developing trends and emerging technologies that may further improve the truck weight regulation practices in China.

2. Characteristics of WIM systems used in China

2.1. Accuracy

For WIM system applications, the truck weight is calculated and corrected using a set of weight measurement data on each axle or axle group of a truck. The error of a WIM system is not only caused by the scale hardware itself but also generated from a number of other sources. Factors such as the quality of system installation, usage and maintenance, vehicle speed, tire friction, and weather conditions all affect the accuracy of the WIM system. Generally speaking, the accuracies of the WIM systems in China are not very satisfying due to the above mentioned factors.

On the hardware side, some manufacturers often exaggerate the performances of their WIM products by presenting the measurement results under ideal or near ideal conditions. On the software side, the users, highway operating agencies, often do not pay enough attention to the system installation and maintenance that is critical to ensure high weighing accuracies. In addition, truck operating characteristics (e.g., speed, acceleration) when passing by a WIM system can also significantly affect its accuracy. In China, some truck drivers try to affect/reduce the weighing readings by performing special maneuvers such as sudden acceleration or deceleration, following an S-shaped trajectory, braking at a very high frequency, and having their tires partly on the weigh pad. Such man-made errors are very difficult to address. Thus, although the typical error of a WIM system is less than 2% during normal road tests, the actual error in real-world applications can be up to 10% (Liu et al., 2010).

2.2. Applicable speed range

China does not have a national standard that specifies the applicable speed ranges for WIM systems (Automatic Instruments, 2006). The speed ranges provided by WIM manufacturers are often a little higher than the speed ranges that these WIM systems are applied to in the real world. This could be because highway operating agencies intentionally lower the speed ranges in order to achieve better accuracy. In truck weight regulation practices in China, the typical applicable speed range for fixed WIM systems is between 10 km/h and 15 km/h. For portable WIM systems, the typical speed range is between 5 km/h and 10 km/h (Liu et al., 2010).

2.3. Weigh scale type

Bending plate and piezoelectric cable WIM scales are usually used for high-speed weighing applications such as the initial screening of overloaded trucks and traffic data acquisition. Such scales can be deployed easily and quickly and require minimum foundation excavation work. The downside is that their accuracies are relatively low. In cases that require high accuracies, such as toll roads using the toll-by-weight method and truck weight enforcement, static weighing devices are more suitable. However, the bending plate WIM scale currently dominates the market of both toll-by-weight highways and weight enforcement in China mainly because of its relatively low equipment and operating costs. Due to the accuracy problem of the bending plate WIM systems, some highway operating agencies have begun to replace or supplement them with static scales.

3. Practice of toll-by-weight in China

3.1. Toll fee structures based on vehicle class

In recent years, many highways and bridges in China have been constructed and financed by local governments and the private sector. The investment is then paid off by collecting user tolls. Initially, most of the tolls were collected based on vehicle class and verified load capacity (see Table 1). Each vehicle class has a different verified load capacity, which is marked on the vehicle license plate. This method is simple and easy to implement. However, the past experience in China has shown that this toll fee structure does not charge vehicles based on their actual damage to the roads (US Department of Transportation, 1997; Conway and Walton, 2008). In particular, heavily overloaded trucks pay less than what their usage of the roadway system is worth. Since toll rates are usually determined partially based on the overall damage caused by all vehicles, this causes those non-overloaded trucks to be overcharged unfairly. Moreover, some heavy truck owners intentionally falsify the verified load capacity information (sometimes with the assistance from truck manufacturers) to pay less tolls. For investors in the private sector and local governments, it is obviously very important to protect the roadway infrastructure from premature failures due to overloaded trucks and to maximize the return from their investments. With truck traffic volumes continuing to grow and limited infrastructure and enforcement resources (e.g., labor, funding, facilities, land), there is an urgent need to find better methods to ensure that highway infrastructure is effectively managed and carefully protected. Particularly, it is critical to make sure that all users are charged fairly based on their actual usage of highways. In China, an emerging and increasingly popular trend is to use WIM on toll roads to facilitate the incorporation of vehicle weights into the determination of appropriate toll rates.

3.2. Toll fee structure based on toll-by-weight in China

The toll-by-weight method charges truck drivers according to the loaded weight. This toll mode was first introduced and used for the Rainbow Bridge in Tianjin in November 2001. Since 2003, Jiangsu, Qinghai, Henan, and other provinces in China have all begun to implement the toll-by-weight method on the provincial

Table 1
Sample toll fee structure based on vehicle class in China.

Vehicle class number	Verified load capacity	Rate (CNY/t km)
First	<2	0.4
Second	2–5	0.7
Third	5–10	1.1
Fourth	10–15	1.32
Fifth	>20	0.08