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Effect of Weight in Motion Detection System on Road Enforcement Network of Hungary

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Abstract

After two years of legislative preparation, the introduction of National Dynamic Axle Weight Measurement System was done in 2018. More than 100 control points were deployed in Hungary. This paper aims to present a brief summary of the technological background of a large-scale integration of High Speed WIM systems, and their effect on road usage. Detailed statistical analyses of preliminary results were conducted. The introduction of vehicle in motion dynamic mass measurement system in Hungary had not caused significant changes in road usage in the investigated period on the investigated road segment. The ratio between nationality (domestic or foreign) of heavy road vehicles had not changed due to introduction of vehicle in motion dynamic mass measurement system.

Keywords

automatic weight enforcement, road usage, by-pass

1 Introduction

Following the example of the Hungarian road toll system and the intelligent road checkpoint system operated by the Hungarian police, the new weight enforcement network will also utilize the 'principle of objective liability'; meaning that in case of a vehicle- or axle-weight limit violation, the administrative procedure is initiated against the transport operator instantly. Legally binding administrative decisions are generated via the exact same way as a fine for speeding, or a fine for unauthorized usage of toll-roads. This means, the margin of error is very small when it comes to vehicle identification and the evaluation of WIM measurement data (WIM – Weight-In-Motion - vehicle in motion dynamic mass measurement). WIM systems are used worldwide, but in most cases for infrastructure protection for instance bridges (Moses, 1979).

In order to reach the unprecedented requirements of the enforcement network, all parties had to work in close cooperation, including the contractors, the regulator, professional representatives of transport associations as well as a great number of technicians, drivers and metrologists involved (Oláh, 2016; Oláh et al., 2018a). Our focus is on the various obstacles, that the integrator, the customer (transport authority) and the administration of metrology had to face while creating WIM certification procedures that are metrologically acceptable, practically feasible, and ready to handle issues specific to the autonomous nature of the enforcement. The networked WIM sites (Fig. 1) and their corresponding road surveillance infrastructure are detecting over 40 million events monthly. Such a vast amount of data shall be collected and processed within the enforcement network in a way that effectively supports traffic control task-groups on-site with real-time

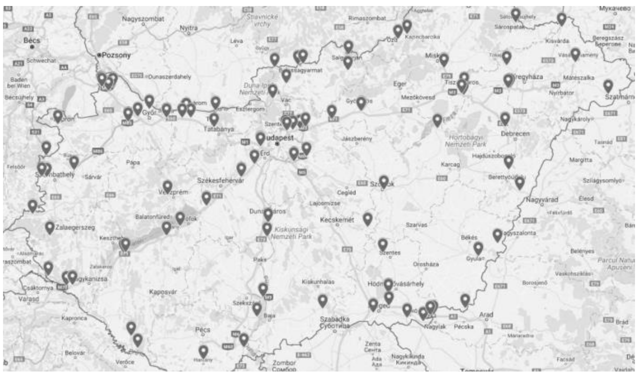

Fig. 1 Location of WIM sites in Hungary (Ronay-Tobel et al., 2019)

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alerts of suspected infringements, is fully compatible with all related governmental IT systems and law enforcement databases, meanwhile respects applicable information privacy and data protection acts (Oláh et al., 2018c). Besides the study of the crucial milestones of the project, the authors give a statistical overview of weighing data in correlation with the main patterns of road freight transport in Hungary (Oláh et al., 2018b). Preliminary technical details were already communicated at the International Conference on Weigh-In-Motion 2018 (Ronay-Tobel et al., 2019).

2 Legislation of Weight-In-Motion

2.1 The proposal of the project

For many years, operating overloaded cargo vehicles has been a 'low-risk high-yield' practice in Hungary. Carriers could achieve remarkable competitive advantage with a very low chance to be randomly chosen for on-site measurement by mobile inspection units (Wang and Wu, 2004). Static weight bridges present a much better inspection coverage, but they inflict significant time loss to lawful carriers and are easily avoided by the less law-abiding ones (Prozzi and Hong, 2007). Project Weight-In-Motion has achieved a major increase in coverage and enforcement efficiency, featuring 107 WIM stations monitoring 274 lanes with approximately 1500 quartz sensors installed. The development was financed (for over 90 Million EUR) by domestic budget and managed by the public-sector consortium of National Transport Authority of Hungary and the National Toll Payment Services Plc. Decision-makers have been guided by the well-known goals of the proposed solution: improvement of *road safety* (as overloaded vehicles pose an increased risk and severity of accidents) (Jacob and Feypell-de La Beaumelle, 2010; Török, 2015) preservation of the general *condition of the roads* (as overloaded axles significantly deteriorate the public roads network; its annual maintenance cost is larger than the total investment of project Weight-In-Motion (Sipos, 2014), creation of a *fair competitive environment* (as law-abiding businesses had to face a market distorted by carriers violating regulations for higher profit) (Oláh et al., 2017). The existing infrastructure of the toll enforcement system provided a cost-efficient method of implementation, utilizing its power-, communication-, and processing capabilities. The system is capable to detect and measure all types of vehicles, including cars, minivans, trailers, motorcycles, but the current regulatory background does not extend to said classes, when it comes to direct enforcement. These drivers still have to comply with applicable weight regulations and may be subject to conventional inspection by authorities.

2.2 Type approval of Weight-In-Motion

Following multiple practice sessions of calibration and certification procedure and the simulation of various failure events, type approval for Weight-In-Motion has been issued in February 2017, specifying the following metrological parameters:

- accuracy class for gross weight: 5; 7; 10,
- range of measurement (gvw): 1.000 kg to n*20.000 kg (n = axle nr.),
- accuracy class for axle weight: E; F; G,
- range of measurement (axle): 3.000 kg to 20.000 kg,
- verification interval: d = 100 kg,
- speed range: 15 km/h to 150 km/h.

The listed accuracy classes and associated tolerances are in compliance with OIML-R134-1 (International Organization of Legal Metrology, 2006). As an integral part of the type approval procedure, the effects of erratic driving behavior and special cargo types (bulk load, liquids – Fig. 2) have been simulated as well under full road closure. The test involved 3 fuel tankers – each with different load levels – 1 trailer truck filled with grain (bulk) and 1 fifty-seat bus. The test has been observed by representatives of carriers' organization.

The results of the experiment showed that all measurements marked as *valid* were within the operational error limits as the WIM system detected:

- 10 out of 10 events as invalid, when the driver applied intense braking on the sensors;
- 6 out of 10 events as invalid, when the driver suddenly accelerated on the sensors;
- 0 out of 10 events as invalid, when consistent driving behavior was followed.

Consequently, none of these cargo types have been excluded from weight enforcement, however domestic fuel carriers, bulk loads and buses obtain additional allowance for axle weight limits after a free registration of the operator.

Fig. 2 Axle load measurement of special reference vehicle (Ronay-Tobel et al., 2019)

Tanker's cylindrical shape can be reliably identified by 3D vehicle laser scanners mounted above WIM sites (Fig. 3).

2.3 Extension of road control methodology

The Roadside Control Information System (KEIR) – built on the framework of Weight-In-Motion – enables complex roadside- and site-inspection, covering the entire spectrum of control, featuring two-way connection with official databases of multiple authorities. KEIR provides information for road control officers, regarding the vehicle (M.O.T. inspections, insurance validity, exemptions), the driver (qualification, driving license, personal data register) and the operator (activity license, penalties, debit, etc.). Control personnel are able to log in to a set of WIM stations and receive real-time alerts. Roadside control is supported with mobile automatic number plate recognition cameras and portable Variable-Message Signs. KEIR automatically generates reports, decisions and related documentation and incorporates an electronic payment platform for handling on-site payments. Resulting data is transferred to back-office in case the administrative procedure continues.

3 Implementation of Weight-In-Motion

Section 3 provides a brief review of the implementation of the Hungarian Weight-In-Motion system. Sensor arrays are installed in two basic configurations:

- 2 sensor rows: used for preselection, calibrated for weighing;
- 3 sensor rows: used for direct enforcement, certified by a notified body.

Quartz sensors are installed in the full width of the road (including emergency lanes) in a single line (Fig. 4) or offset, depending on available lane width. The system is prepared to measure vehicles passing in-between two parallel lanes.

WIM units are located in roadside cabinets equipped with door opening detection and connected to the gantry via protective tubing in order to prevent sabotage attempts. Measurement-critical hardware components are locked and sealed by the assigned regional office of metrology,

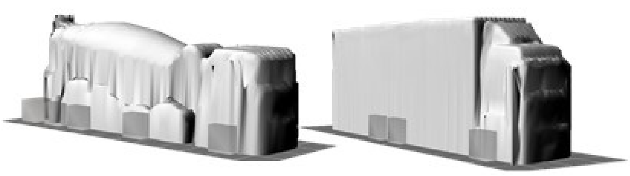

Fig. 3 3D imagery of different trailer superstructures (Ronay-Tobel et al., 2019)

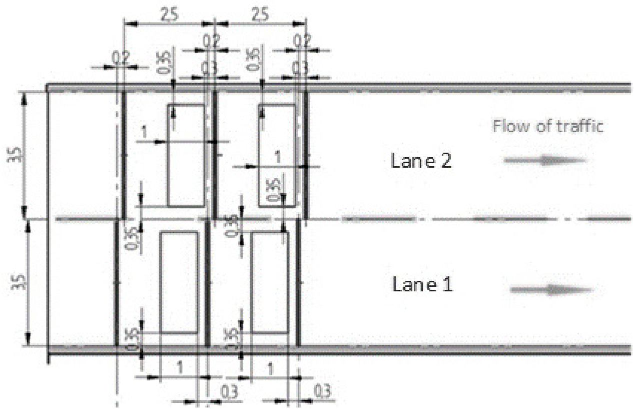

Fig. 4 Typical single-line layout featuring 12 quartz sensors and 4 loops (Ronay-Tobel et al., 2019)

the data-label and printed reports containing calibration constants are placed inside the cabinet, bearing a unique validating sticker. Preceding the installation, road surface (and in some cases the base layer too) has been replaced in order to meet 'Class I – Excellent' quality parameters stated in COST 323 specification, providing appropriate geometric and mechanical conditions for high accuracy measurement (Jacob et al., 2002).

Statistical dispersion of measurement error of gross vehicle weight is characterized by 2.0–2.5% interquartile range (IQR), with sites featuring only two sensor rows and lower road quality classification having usually +0.5% higher IQR as seen in the boxplot below (Fig. 5). The boxplot covers a specific subset of reference vehicles that were present at the verification of both certified and non-certified (preselection) stations, therefore unloaded vehicles are excluded. Presented dataset should be considered as a base of comparison of site-layouts rather than representative benchmark of quartz technology.

3.1 Summary of Live Operation

Although the system started to work on September 2017, automatically generated administrative fines for weight

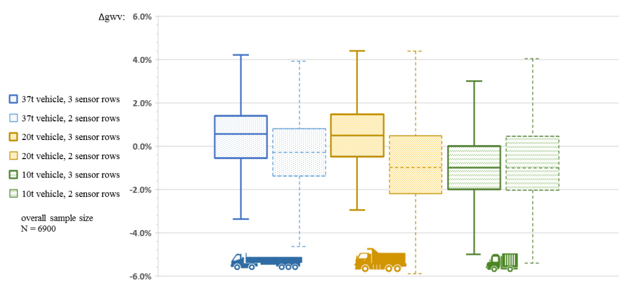

Fig. 5 Distribution of relative error for gross weight of loaded reference vehicles (Ronay-Tobel et al., 2019)

limit violations based on WIM data began to be sent out in July 2018. Huge amount of data has been collected. In Fig. 6(a) J2 vehicle class category was summarized on M1, M7, M85 Hungarian motorway for research purpose.

In Fig. 6(b) J3 vehicle class category was summarized on M1, M7, M85 Hungarian motorway for research purpose.

In Fig. 6(c) J4 vehicle class category was summarized on M1, M7, M85 Hungarian motorway for research purpose.

The analysis of data showed that no significant change in road usage were detectable. The ratio of foreign vehicles to domestic ones has not fluctuated significantly.

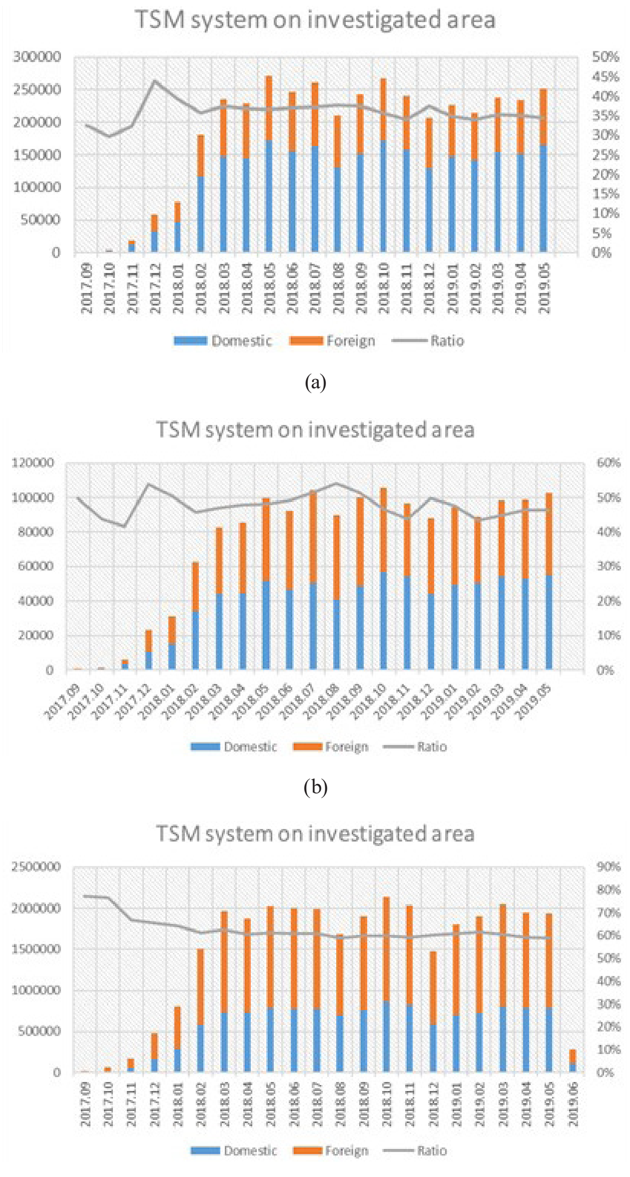

Fig. 6 Summary of Live Operation system (a) Time distribution of J2 vehicle class on investigated area; (b) Time distribution of J3 vehicle class on investigated area; (c) Time distribution of J4 vehicle class on investigated area

Due to the lack of comprehensive international experience in the field of direct-enforcement, various measures had been taken during the introductory period of the system, such as temporary tolerances for vehicle weight and separately scheduled activation of WIM sites. During the first 7 months of operation, 10–15% of the certified sites were involved in Live Operation at a given time, in periodic rotation. Fines were applied on 1294 occasions, for the total value of 62.6 million HUF. This is a 5x increase compared to the five-year average performance of mobile inspection units (Fig. 7).

4 Conclusion

Author's intention with this case study was to give an insight on the major advantages and obstacles of operating a WIM system featuring full road network coverage and direct enforcement mode and present an example for other national authorities contemplating similar projects in the near future. Apart from the lower acquisition costs provided by the in-bulk purchase of hardware, and a number of site specific services – such as calibration and maintenance – being conducted in a cost-efficient way, what really made the implementation financially feasible was the efficient utilization of the national road toll system. Vehicle detection, ANPR functionality, gantries with power and communication outlets were already granted on the sites, hence the duplication of roadside infrastructure could be avoided completely. Another advantage of full network coverage happened to be the potential for self-correction, and the immediate detection of sites/sensors with their accuracy suspected being below required level. A central monitoring application to exploit this potential is currently under development for weight-In-Motion. Looking at the challenges: the larger the WIM network, the larger risk one has to handle to achieve and maintain public trust, which is a key factor for every governmental body managing an automated control system. One single undetected

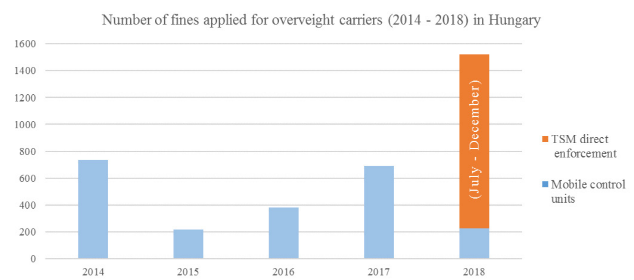

Fig. 7 Annual nr. of fines imposed on overweight trucks (Ronay-Tobel et al., 2019)

malfunction, or a sudden change in road conditions may lead to dozens of wrongful infringement fines, followed by the protest of carrier's organizations. With that in mind, the Ministry for Innovation and Technology of Hungary consciously followed a transparent approach by:

- announcing an introductory period, while imposing informal administrative decisions instead of actual penalties;
- organizing an open trial-session, with all carriers' organizations invited to put the metrologically certified system to a test;
- publishing printed and online brochure, supported by TV campaign and a dedicated homepage (Nemzeti Tengelysúlymérő Rendszer, online);
- opening online user interface from which carriers can download WIM data (and photos) related to their own infringements;
- taking part in a conference series so-called '*Roadshow*', that provided local transport companies with opportunity to express their concerns on a public forum;
- developing SMS service that provides immediate notifications for registered carriers, in case one of their trucks would be detected over its respective weight limit.

So far, these measures have proved to be an effective method to preserve the public acceptance of Weight-In-Motion and Weigh-In-Motion in Hungary. The next step is to review the effects and practical consequences of the legislative changes described in Subsection 2.2, and to establish the aforementioned central monitoring functionality before switching all remaining sites into direct enforcement mode.

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