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ANALYSIS OF THE REQUIREMENTS FOR HIGH SPEED PRESELECTION VEHICLE WEIGH-IN-MOTION SYSTEMS ON THE BASIS OF COMPLETED PUBLIC CONTRACTS

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Abstract – The paper summarises selected requirements from public contracts, relating to WIM preselection systems in Poland. The difference between WIM and HS-WIM requirements is presented, and the differing requirements based on both international documentation and the standardised requirements that new or refurbished stations must meet are described[1].

Key words – HS-WIM, road safety, road protection, weigh-in-motion systems, WIM

JEL Classification – R41, R42

INTRODUCTION

Weigh-in-Motion (WIM) preselection systems are systems that allow dynamic measurements of the total weight of a vehicle passing through sensors installed in the road pavement. They are also designed to measure the axle load of the vehicle. The results of the measurements are subject to a large error, so they are intended for preselection, i.e. the selection of vehicles that are very likely to be over the maximum permissible weight or over the permissible axle load. International or foreign requirements, standards or recommendations with regard to vehicle preselection weighing systems are included in documents such as COST 323 [1], OIML R 134-1 [2] or ASTM E1318-09 [3]. More broadly, they include information such as a breakdown by vehicle class, the magnitude of the measurement error and level of accuracy, and the definition of the temperature range over which the load cells take measurements.

The purpose of the article is to compile and compare the procurement of WIM pre-selection systems with national and international requirements, and to perform a summary on the maintenance of the necessary documentation for the WIM position and to systematize information on the requirements and the possibility of converting WIM positions to HS-WIM positions with the possibility of imposing penalties on drivers who exceed acceptable weight standards.

The introduction of High Speed Weigh-in-Motion (HS WIM) is based on the same principles as the preselection system, with the difference that:

- the exact error relating to each measurement will be determined, and not, as in the case of preselection systems, the level of significance of the measurement,
- it is required that the system is validated, i.e. it is a measuring device,
- the system would be part of a regulated administrative system, making it possible to impose penalties on offending drivers.

The difference between the WIM preselection system and the HS-WIM is shown in Figures 1 and 2.

[1] **This paper was written within the framework of the GOSPOSTRATEG project, contract with NCRD No. GOSPOSTRATEG9/000X/2022 "Automatic vehicle weigh-in-motion system"**

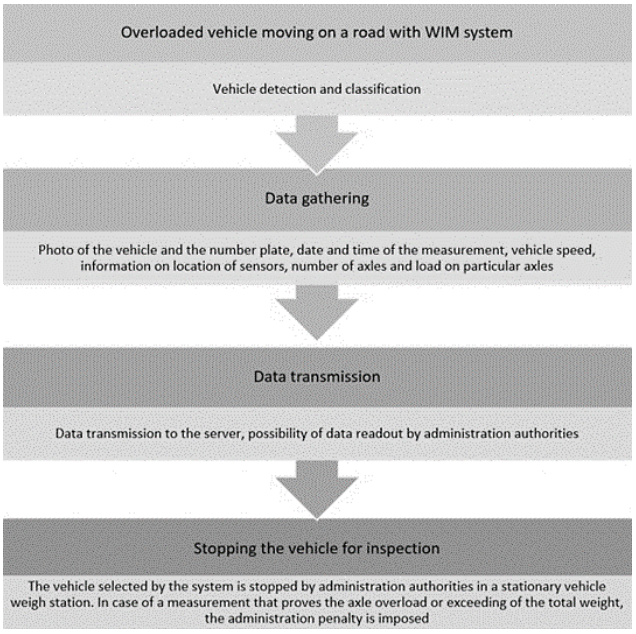

Fig. 1. Example of vehicle weighing scheme (preselection system)

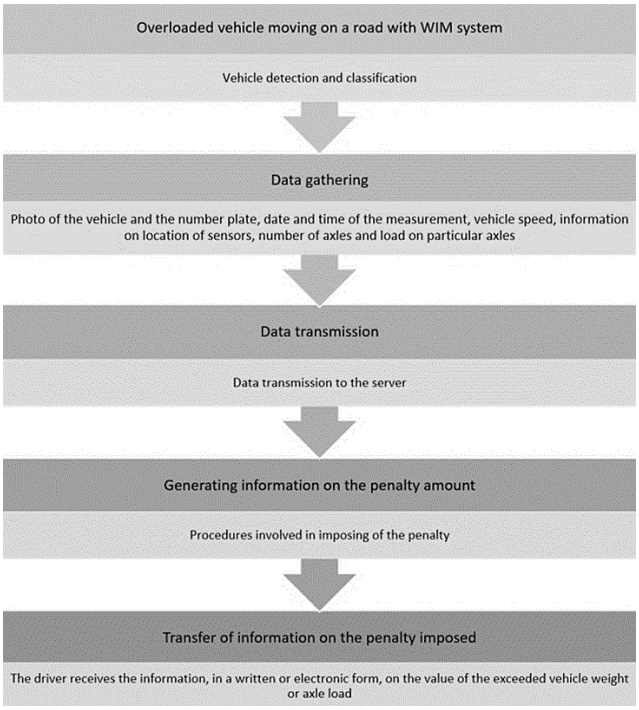

Fig. 2. Example of vehicle weighing scheme (HS-WIM)

The paper presents a summary of the contract of preselective WIM systems and systematises the requirements by category.

1. ANALYSIS OF SELECTED CONTRACTS OF PRESELECTION SYSTEMS IN POLAND

This paper examines a contract that concerned a preselection system commissioned from Białystok with the number DM-IV.271.8.2020 in 2020. [4]. It concerned the design and the repair of the preselection weighing system. It was only possible to start construction work on the basis of prepared and approved design documentation and surveying services based on a post-inventory map containing technical infrastructure development facilities, land development and the dimensions of the facilities. The tasks of completing the contract also included work on organising and securing the construction site, organising traffic and ensuring access to the buildings located next to the project, restoring horizontal marking, top layers of pavement, topsoil, greenery and the site housekeeping after the work had been completed.

The existing pavement structure meeting the KR6 traffic load category consisted of:

- 5 cm thick BA 0/16 wearing course with modified asphalt (basalt aggregate),
- 8 cm thick BA 0/20 binder course with modified asphalt (granite aggregate),
- 18 cm thick BA 0/25 base course,
- ancillary subbase layer of mechanically stabilized crushed aggregate with the thickness of 22 cm
- reinforcement layer of cement stabilized soil with Rm=2,5 MPa with the thickness of 25 cm,
- top frost-protection course made of non-expansion soil (filtration coefficient $K \geq 8$m/d, bearing capacity index CBR > 40%) with a thickness of 25 cm.

The scope of work included the reconstruction of the induction loops, the incorporation of a mounting frame for one of the damaged weighing plates, the removal of the four weighing plates and the re-installation of the weighing plates or strain gauges (to achieve measurement accuracy in accordance with COST 323 - CLASS B+(7) requirements. Subsequently, an overlay meeting the requirements of traffic load category KR6 in terms of longitudinal and transverse evenness was constructed on the road pavement, upstream of the preselection point with the length of 100 m and downstream of the preselection point with the length of 50 m and, in places where the weighing plates were removed and reinstalled, a full roadway structure including foundation footings that also meet the aforementioned traffic load category. In terms of longitudinal and transverse evenness studies, COST 323 requirements were to be met before and after the project. Tasks included connecting the measurement system to the existing one and setting up communications, calibrating and validating the system. An "operational system" is understood to mean the launch of the website containing the measurement data, the operation of a camera designed to take pictures of the vehicles and their number plate, the readout of the number plate, the classification of the vehicles by the system according to the COST 323 criteria. The accuracy of the measurements should be in accordance with the COST 323 specification level B+(7). The documentation necessary for the final acceptance should consist of a final inspection report with annexes to the final acceptance protocol. The system performance requirements (verification tests) were to include recording from video cameras for a minimum of 14 days with data storage on a server, with a maximum of 60 seconds between measurement and web readout. The contract did not include scopes of work for system inspection and maintenance.

Another example analysed is a public contract that was carried out in the Szczecin area with the designation GDDKiA O.Sz.D-3.2413.19.2018 [5] in which the scope of work included the maintenance, adjustment, calibration and performance of verification tests of the preselection system. The above-ground works consisted of the construction of a support structure made of weather-resistant metal (lattice) elements for the installation of cameras above the roadway at a distance that ensures the proper operation of the system (behind the vehicle weigh station) and house-keeping works (the contract provides an example of securing internet or power cables if they are discovered as a result of the works). In addition, the works also included the removal and installation of the preselection point, replacement of induction loops, weighing sensors, and consisted of the design and construction of a concrete footing for a single lane with the assurance that the installation of the system in the pavement would not impair the flow of vehicles. Tasks also included repairing latent defects caused by operation or vandalism. The ground and pavement repair works include repairs at the sensor locations (filling in of grout, aggregate and binder, cracks formed at the sensor-pavement interface), preceded by work to design and construct a concrete footing for a single lane. The contract included work to ensure the continuous operation of the internet connection responsible for accessing data from the preselection station, software and the system, together with maintaining power supply to each component. The operating range of the electronics should be between -40°C and +70°C. Access to the data from the preselection station should be provided via a web browser, as well as the

transmission of data packages should be carried out to the GDDKiA server in accordance with the standards contained in Appendix No. 1 to the "Data transmission instructions for users of the vehicle weighing system" public contract [6]. The requirements for measuring sensors should be based on COST 323 specifications and meet measurement accuracy in accordance with B+(7), with an axle load measurement range between 500 kg and 20,000 kg, an operating range of -40°C to +80°C, and the sensors should be able to withstand over-speeding, sudden acceleration, braking, and withstand 250 kN/axle loads and the passage of special vehicles (e.g. tracked vehicles). The implementation of the contract was also based on the requirement that the detection of overloaded vehicles should be reliable and that, in the event of a faulty sensor, it should be possible to replace it easily. The sensors should be installed in such a way that they cannot be bypassed by the vehicle. The camera system should record 99% of all vehicles exceeding the permissible parameters, along with the ability to read the number of axles of the vehicle, number plates. The preselection system should correctly classify vehicles and load measurements (vehicle axle and individual wheels) and total weight should be made with an accuracy of B+(7), the distance between adjacent vehicle axles with an accuracy of B(10). The above requirements are in line with COST 323 specifications. A properly functioning system is one in which it is possible to recognise multiple and single vehicle axles, the results of measurements relating to the total vehicle side load and vehicle length measured by means of inductive loops and to display information about a vehicle that has exceeded the permissible height, axle load, axle groups, total weight or speed (with measurement accuracy B(10) in accordance with COST 323, together with the lane in which the vehicle was travelling and its direction, assigning a unique number to the passing vehicle. Classification of the vehicles is to be based on the BAST TLS 8+1 classes [7] and COST 323, and the date and time of the journey should be synchronised with the time standard (Central Office of Measures, Time and Frequency Laboratory).

Verification tests could be carried out with appropriately classified vehicles (according to the BAST TLS 8+1 classification shown in Table 2 and the COST 323 classification shown in Table 3) and are carried out in accordance with the guidelines of the GDDKiA (Table 1) and contained in the "Test of the vehicle weigh-in-motion stations verifying the level of detection, identification and classification of vehicles" document. [8], whereby the correctness of the indication of the relevant vehicle classification can occur at a level of 80% for each class, according to COST 323 classification.

Table 1. Correctness of vehicle classification [1, 5]

	Correctness of classification
For motorbikes:	≥ 90%
For passenger cars:	≥ 97%
For delivery vans:	≥ 90%
For passenger cars with a trailer:	≥ 90%
For trucks:	≥ 90%
For trucks with a trailer:	≥ 95%
For semi-trailer vehicles:	≥ 95%
For buses:	≥ 90%

Table 2. Vehicle classes according to the BAST TLS 8+1 classification [5, 7]

No.	**Category description**	**Category symbol**
1.	Motorbikes	10
2.	Passenger cars	7
3.	Passenger cars with trailer	2
4.	Delivery vans	11
5.	Trucks	3
6.	Trucks with trailer	8
7.	Tractors for semi-trailers	9
8.	Buses	5
9.	Unclassified vehicles	6

Table 3. Vehicle categories according to COST 323 [1, 5]

No.	Category description	Category symbol
1.	Passenger cars, passenger cars with lightweight trailers or caravans (< 35 kN)	1
2.	Two-axle trucks	2
3.	Three- and more axle trucks	3
4.	Single-axle or two-axle tractor units in the group	4
5.	Three-axle tractor units in the group	5
6.	Trucks with trailer	6
7.	Buses	7
8.	Other vehicles	8

Tests are considered successful if the system operates reliably around the clock with access to measurements via an app and a web browser and it is possible to view the registered vehicle up to 30 days back. Camera images are transmitted at a frequency of every 10 minutes. Photographs of 100 consecutive offending vehicles, regardless of weather and lighting conditions, should be met at least 95% of the time (photos should have the driver's cab area concealed). Photographs of the number plates of each passing vehicle should be at a level of 95% with a readout of no more than 1h, and their numbers in text at a level of at least 90% for each vehicle. The contract analysed did not relate to inspection and maintenance.

In the area of security of the confidential data transmission, requirements included a current SSL certificate from a trusted authority, user authentication with a login and strong password with the possibility of locking the account if the login attempt was unsuccessful and exceeded three attempts. Accounts should have an appropriate level of authorisation and an operation event log should be kept.

The third contract analysed was the contract from Bydgoszcz with the number GDDKIA.O.BY.D-3.2421.19.2022.26 [9], consisting of the maintenance of the vehicle preselection system. The scope of work included the infrastructure of the system in order to keep it in proper working order, including repairs of latent defects and failures caused during operation or acts of vandalism, damage, collisions, accidents or incidents, as well as minor repairs to the pavement, i.e. making seals. Tasks in terms of the correct operation of the system included ensuring that the software and the system remained operational at all times, including the sharing and transmission of collected data through both the application and the central database. The requirements with regard to vehicle detection and registration were to be a minimum of 99%, and both these and other requirements are the same as those described in the contract from Szczecin (No. GDDKiA O.Sz.D-3.2413.19.2018). The performance of the verification tests should be in accordance with the GDDiKA procedure "Test of the vehicle weigh-in-motion stations verifying the level of detection, identification and classification of vehicles" [8].

In addition to the aforementioned work, tasks included cyclical inspections based on data sheets and as-built documentation. The contract included examples of work such as: measurement of fire protection effectiveness by a certified person, inspection of the technical condition of the support structure, inspection of the technical condition of the foundations, measurement of protective earthing, etc. As part of the completed task, a laptop with the minimum parameters and technical specifications indicated, containing an application designed to handle data from the preselection station, was to be handed over.

The fourth example was a contract from Bydgoszcz (No. GDDKiA.O.BY.D-3.2413.16.2015.35), which included work on the ongoing maintenance and adjustment of the preselection system together with calibration and verification tests. The requirements of the contract were to restore, after completion of the works, the lane area to its previous condition. The scope of work included minor repairs, consisting of filling cracks at the interface between the induction loops and sensors and the pavement, losses in aggregate and binder, and cracks in the pouring compound of the sensors. The requirements in terms of correct operation overlap with the contract from Szczecin (No. GDDKiA O.Sz.D-3.2413.19.2018), with calibration of the system planned to be carried out at least once a year, between April and May. The requirements for the verification tests are based on documentation from the General Directorate for National Roads and Motorways (GDDKiA) ("Procedure for verification of weigh-in-motion stations" [5] and "Test of the vehicle weigh-in-motion stations verifying the level of detection, identification and classification of vehicles" [8]. A report was required from each test.

The requirements for the web-based application included access to information on registered vehicles

over the last minimum of 30 days with the specified criteria in the contract. Also with regard to the verification tests, the requirements overlap with the contract of the GDDKiA in Szczecin (designation GDDKiA O.Sz.D-3.2413.19.2018). As part of the contract, the Employer is obliged (for the duration of the contract) to carry out a quarterly report on the condition of the pavement, the completeness of the data on the central server, information on the number of defects and failures, the completeness of inspections of system equipment components and system maintenance. Maintenance or inspection is understood to be, among other things, ongoing work such as checking the condition of the systems cabling, repairing damage to the power supply cable line, technical inspection of the gate structures with foundations, testing and/or tuning the inductance of the induction loop, diagnosing the correct operation of the pressure sensors, cleaning and painting pavements where corrosion has occurred.

2. ANALYSIS OF REQUIREMENTS FOR WEIGHING ACCURACY AND VEHICLE CLASSIFICATION

All the preselection system requirements included in this paper are based on the requirements of the COST 323 specification and relate to:

- vehicle categories (Table 3),
- measurement accuracy (at the required level B+(7) or B(10) as set out in Table 4).

Table 4. Required measurement accuracy for the weigh-in-motion preselection system [1]

Criterion	Accuracy grade; confidence range - δ (%)	Accuracy grade; confidence range - δ (%)
	B+(7)	B (10)
Total weight (> 3.5 t)	7	10
Axle load (>20kN)		
Single axle load	11	15
Axle load in the group	14	20
Group axle load	10	13
Axle distance	3	4
Speed	3	4

3. EXAMPLE OF A SET OF REQUIREMENTS FOR THE ROAD HIGH SPEED VEHICLE WEIGHING SYSTEM

The requirements include cleaning and excavation work, i.e. proper preparation of the location where the weigh-in-motion system will be installed (installation of gantries on which cameras will be mounted, incorporation of induction loops and sensors into the pavement, electronic equipment with appropriate covers such as technical cabinets) and proper preparation of the pavement meeting the requirements according to COST 323 specifications, thus performing work on monitoring the pavement condition and repairing any cracks in the areas where the pavement meets the induction loops or sensors.

Requirements for the accuracy of sensor measurements are set at level B+(7) according to COST 323 for the measurement of axle load, individual vehicle wheels, with a measurement range for axle load of 500 kg to 20,000 kg, at temperatures from -40°C to +80°C, and an improved operating range for the rest of the electronics constituting the measurement system in the temperature range from 40°C to +70°C. The measurement accuracy requirement for the distance between axles should be B(10) in accordance with COST 323 specifications. Vehicles are classified using the BAST TLS 8+1 category as shown in Table 2, which shows the classification accuracy levels and the COST 323 classification, where the classification accuracy level is the same for each vehicle at 80% (Table 1). The system should be integrated with the Central Office of Measures (Time and Frequency Laboratory) to synchronise the date and time of vehicle passages. The data collected from the system should be sent to the central server in accordance with the requirements set out in the dedicated GDDiKA document, the requirements also relate to the frequency of sending images from cameras (e.g. once every 10 minutes), and the collected data should be available for 30 days from the date of measurement, with the image of the driver's cab to be obfuscated and the number plate to show only the first three characters.

Cameras included in the WIM system should be equipped with infrared light emitters (940 nm) and automatic number plate recognition with a 90% read rate requirement.

The system should have an emergency power supply to maintain system operation for up to 12 hours and be equipped with earthing, surge, lightning and electrical interference protection.

To verify the correct operation of the system, documents have been developed by the Directorate General for National Roads and Motorways, which include appropriate verification tests and a series of cyber security requirements and appropriate safeguards.

The requirements for inspections and maintenance were usually based on the completion of reports on system components – from checking the completeness of data collected to corrosion protection.

CONCLUSIONS

An analysis of the contracts of the WIM preselection points makes it possible to conclude that, despite the difference in the scopes of the contract (renovation, repair or maintenance work), the stations were based on a standardized system of work, i.e. they were similar in parameters and scopes. It is worth noting that where the Employer incurred the costs in terms of laboratory testing of the pavement, it was the contractor who was charged with the costs associated with bringing the pavement up to applicable requirements accordingly. These arrangements were set out in the agreement and guaranteed the correctness of the work carried out.

The combination of the requirements of COST 323, the BAST TLS 8+1 classification and the mandatory internal requirements of the Directorate General for National Roads and Motorways (GDDKiA) resulted in standardised requirements for the measuring stations and, consequently, in the documentation developed by the GDDKiA concerning the requirements for system components such as:

- Data transfer instructions for users of the weigh-in-motion system,
- Procedure for checking weigh-in-motion (WIM) stations,
- Test vehicle baseline measurement protocol,
- Guidelines for testing road pavements within the measuring sensors of vehicle weighing systems (Requirements and test procedure for verification of WIM measuring locations),
- Transmission of data in XML format via http,
- Dates for calibration with verification of the measurement accuracy of the pre-selection weigh-in-motion station and a full functional check of the preselection weighing system,
- Guidelines for process ducts,
- Failure report template,
- Quarterly works acceptance protocol template,
- Failure remedy report template.

ABBREVIATIONS

1. **GDDKiA** – General Directorate of National Roads and Motorways;
2. **WIM** – Weigh-in-Motion
3. **HS-WIM** – High Speed Weigh-in-Motion.

ANALIZA WYMAGAŃ DLA SZYBKOPRZEJAZDOWYCH PRESELEKCYJNYCH SYSTEMÓW WAŻENIA POJAZDÓW W RUCHU NA PODSTAWIE ZREALIZOWANYCH ZAMÓWIEŃ PUBLICZNYCH

W artykule zestawiono wybrane wymagania pochodzące z zamówień publicznych, dotyczących systemów ważenia preselekcyjnych WIM w Polsce. Przedstawiono różnicę pomiędzy wymaganiami WIM i HS-WIM oraz opisano zróżnicowane wymagania zarówno na podstawie dokumentacji międzynarodowej jak i ujednolicone wymagania jakie muszą spełniać nowe lub remontowane stanowiska.

Słowa kluczowe: bezpieczeństwo ruchu drogowego, HS-WIM, ochrona dróg, systemy ważenia pojazdów w ruchu, WIM.

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