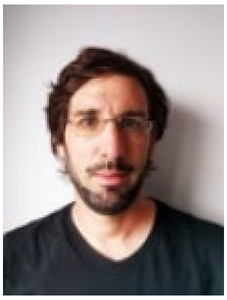
DETERMINING THE TRAFFIC LOAD DISTRIBUTION ACROSS A LARGE PORTION OF THE ROAD NETWORK WITH SHORT-TERM B-WIM MEASUREMENTS: A CASE STUDY OF THE REPUBLIC OF SERBIA



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Abstract

Overloaded heavy goods vehicles are the main cause of the deterioration of road surfaces. The first step in tackling the problem of overweight HGVs is the determination of the status quo, upon which a state authority can build an effective investment strategy for the cost-effective implementation of weigh-in-motion systems and automatic traffic counters.

In 2020, the Public Enterprise Roads of Serbia (PERS) oversaw a state-wide project where 17 bridge weigh-in-motion measurements were conducted across the Republic of Serbia in 3 months. The most problematic road sections from the point of view of overweight HGV's were identified through these measurements, as well as real ESAL values and the estimated remaining lifespan of each road section. In the second phase, which is yet to be implemented, permanent road weigh-in-motion installations are planned on the most affected parts of the road network, as well as additional bridge weigh-in-motion measurements.

This paper presents an overview of the bridge weigh-in-motion project in the Republic of Serbia and describes the WIM implementation strategy followed by PERS.

Keywords: bridge weigh-in-motion, WIM, Republic of Serbia, ESAL, infrastructure management

1. Background

In 2020, the Public Enterprise Roads of Serbia (PERS) issued a tender where one of the tender items was bridge WIM measurement service at 17 locations. The aim of the project was to get an overview of traffic loading across the Serbian road network based on a series of two-week bridge WIM measurements.

Data on traffic loads is crucial in pavement design and maintenance. The vast majority of information on traffic loads is still being collected by traffic counters, which do not gather data on actual traffic loads but instead count vehicles and assign them predetermined traffic load values. In cases where the composition of heavy traffic significantly differs from long-term averages, data from traffic counters can substantially underestimate the actual traffic loads exerted on the pavement by HGVs, which can have a detrimental effect on the longevity of a road section. While weather, climate, geological factors, and other environmental parameters do affect the pavement, "heavy traffic causes the most important failures in a pavement, producing fatigue cracking and rutting that require pavement rehabilitation" (Pais et al., 2013).

Weigh-in-motion (WIM) systems weigh every passing HGV and determine its axle loads, making them a source of data on actual traffic loads. Broadly speaking, there are two types of high-speed WIM systems: road WIM systems, whose sensors are carved into the pavement, and bridge WIM systems, where sensors are installed on the bottom side of a bridge. Road WIM systems are installed in permanent locations and can achieve the highest accuracy. Bridge WIMs, on the other hand, are portable and can be used for short-term measurements. The strategy being implemented by PERS aims to utilize the advantages of both types of high-speed WIM systems.

Furthermore, traditional traffic counters often do not differentiate between types of heavy vehicles, such as trucks or buses, which can have significantly different effects on pavement deterioration due to differences in axle load configurations. Weigh-in-motion systems, on the other hand, can provide data on vehicle characteristics and weight distribution, allowing for a more accurate assessment of pavement damage and the development of targeted maintenance and rehabilitation strategies. Thus, the use of WIM systems can help improve the overall durability and safety of the road network, which can have significant economic and social benefits.

2. Overview of PERS's Strategy

Bridge WIM measurements were financed through the International Bank for Reconstruction and Development as part of the Road Rehabilitation and Safety Project (RRSP), which is a larger program to support the Government of the Republic of Serbia in the implementation of the National State Road Network Rehabilitation Program. Before the commencement of this project, there was no reliable information on the traffic loading on the Class IA and IB roads, which would be needed in the design and maintenance of road pavements and bridges and the enforcement of overloading.

The use of bridge WIM measurements is a key component of PERS' strategy to improve the design, maintenance, and enforcement of road infrastructure in Serbia. The project aims to provide reliable information on traffic loading, which is essential for the proper design and maintenance of road pavements and bridges, as well as for the enforcement of overloading regulations. This information will also help to identify areas where overloading violations occur most frequently, allowing for targeted enforcement efforts.

The strategy was implemented in two phases, with the first phase involving the installation of portable bridge WIM systems on Class IA and IB roads under a large number of existing bridges or culverts. This provided PERS with a baseline of data on traffic loading, which was needed to plan the implementation of further WIM systems, evaluate the effects of overloading on the infrastructure, and identify hotspots where the largest violations of legislation occur. The portable WIM systems were used to collect short-term data on traffic loading, which was then analyzed to determine the traffic load distribution across the road network.

In the second phase, which is yet to be implemented, permanent road WIM systems will be installed on Class IA roads with the highest intensity of traffic. These systems will be used to record the development of actual traffic loading over a period of several years at a small number of locations. The data collected from the permanent WIM systems will be used as a pre-selection tool to assist in overloading controls and enforcing legal loading limits. This will enable PERS to monitor the development of traffic loads over time and make more informed decisions about the design and maintenance of road infrastructure in Serbia. Overall, the PERS strategy demonstrates a comprehensive approach to improving road infrastructure and ensuring the safety of road users in Serbia.

3. Execution of the Project

After the tender process was concluded, the practical implementation of the project began. The execution of the 17 two-week measurements, which took place between October and December 2020, consisted of the following phases:

- bridge survey and bridge selection
- measurements
- traffic analysis reports

3.1 Bridge Survey and Bridge Selection

Before the commencement of the project, PERS compiled a list of 17 proposed bridges where the measurements were to take place. The measuring locations were scattered throughout the road network of the Republic of Serbia, all of the roads were either the IA (motorways) or IB (state roads) class roads according to the Serbian road classification.

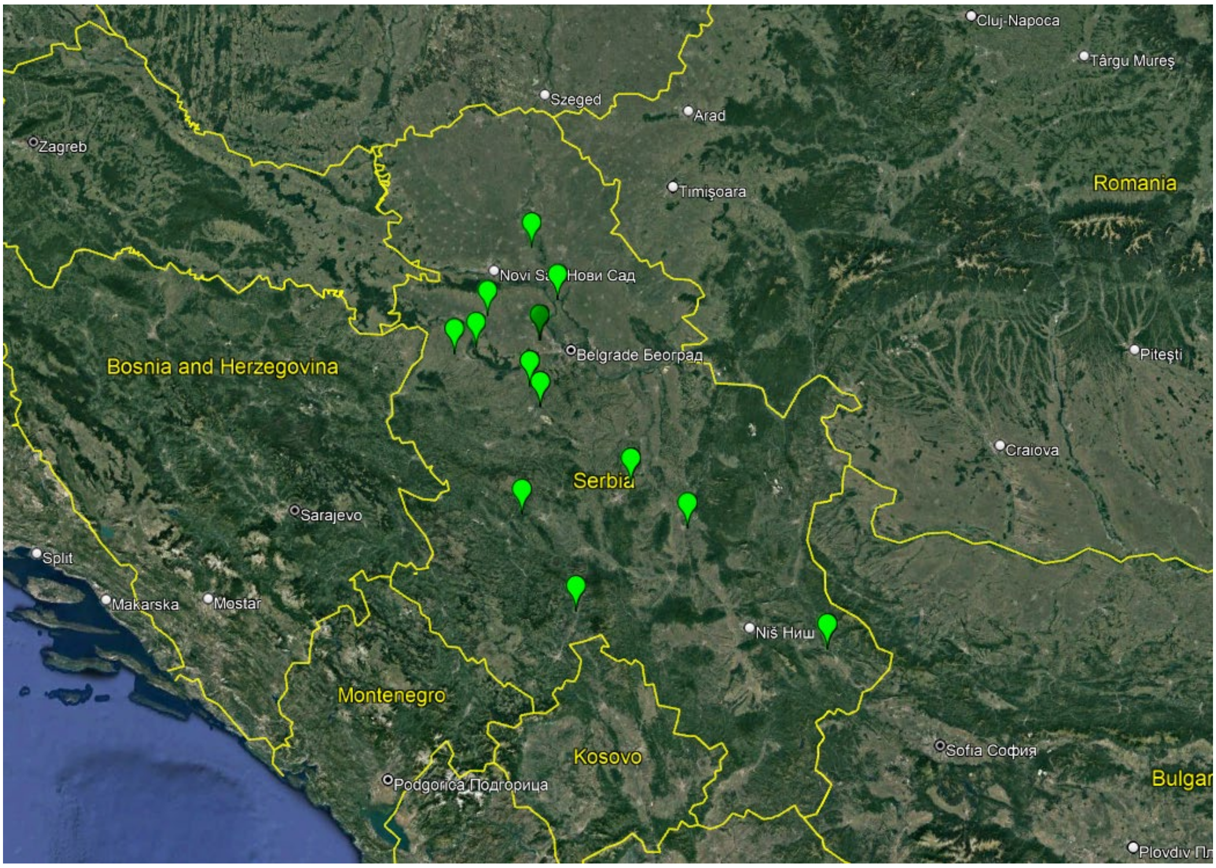


Figure 1 – Measurement locations

Bridge experts inspected all of the proposed sites and checked different parameters that could affect either the quality of the WIM measurement or the logistical execution of the project.

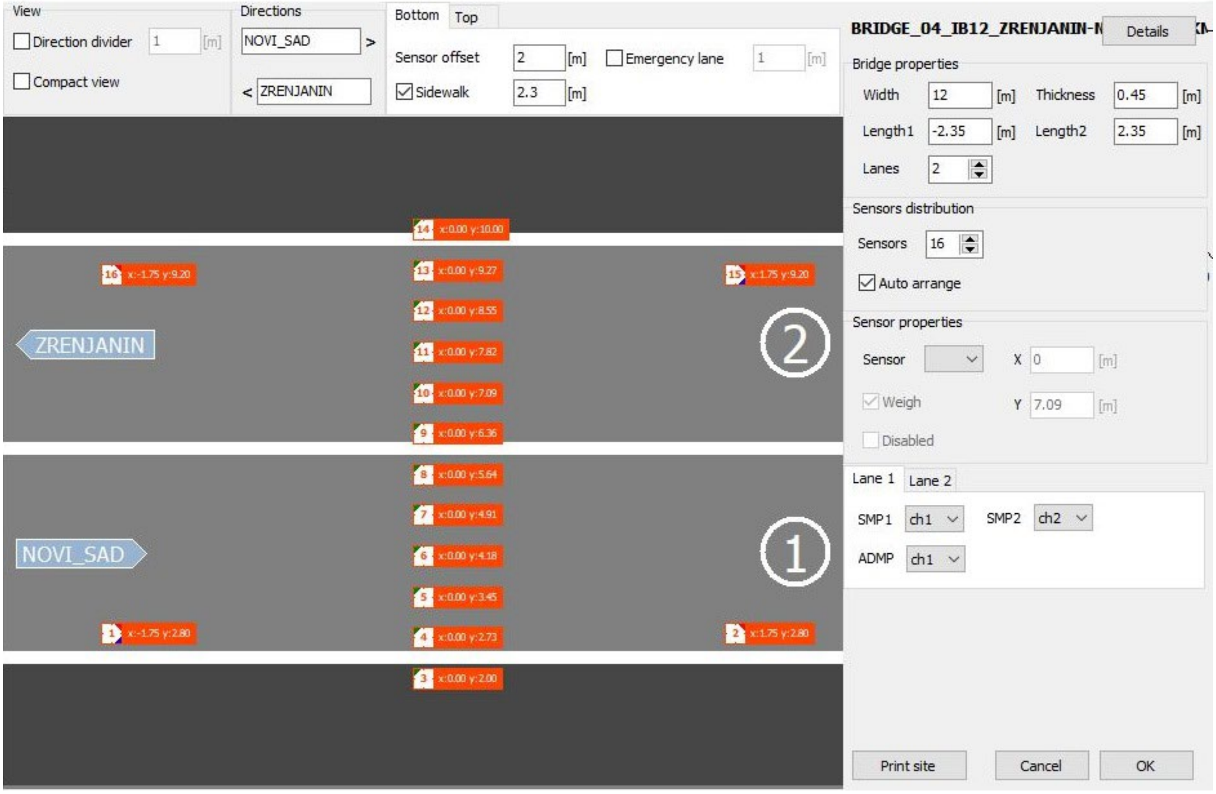
The main parameters affecting the quality of the measurement are the following:

- geometrical characteristics of the bridge
- number of lanes
- bridge type
- quality of pavement and expansion joints
- traffic flow

The parameters, affecting the logistics of a bridge WIM measurement, are the following:

- height of the bridge
- accessibility
- mobile network coverage
- power options

Upon inspection, all the proposed measuring sites were approved for the measurements, and a configuration schematic was prepared for each bridge, which showed the exact position of sensors under the bridge (Figure 2).



View
☐ Direction divider 1 [m]
☐ Compact view

Directions
NOVI_SAD >
< ZRENJANIN

Bottom | Top
Sensor offset 2 [m]
☐ Emergency lane 1 [m]
☑ Sidewalk 2.3 [m]

BRIDGE_04_IB12_ZRENJANIN-N

Bridge properties
Width 12 [m]
Thickness 0.45 [m]
Length1 -2.35 [m]
Length2 2.35 [m]
Lanes 2

Sensors distribution
Sensors 16
☑ Auto arrange

Sensor properties
Sensor
X 0 [m]
☑ Weigh
Y 7.09 [m]
☐ Disabled

Lane 1 | Lane 2
SMP1 ch1
SMP2 ch2
ADMP ch1

Figure 2 – Schematic showing the position of bridge WIM sensors on the soffit of a bridge

3.2 Measurements

The project deadline determined by PERS was the end of December 2020, all of the measurements and analysis reports thus had to be finished between October and December. Due to a short deadline, measurements were simultaneously performed with five portable bridge WIM systems, which were transferred between locations.

Installation and Calibration

The installation of bridge WIM systems took on average less than 8 hours. Due to the height of the soffit of the bridge, a bucket truck was required at 5 locations, while a ladder was used at the rest of the installations. A one-lane short-term road block was set up on locations where a road passed under the bridge due to safety regulations.

After the sensors were placed, the bridge WIM systems were either connected to the power grid, to the methanol fuel cells or they were powered by solar panels.

Figure 3 – Installation of bridge WIM sensors

The systems were calibrated a day after the installation according to the NMi WIM calibration protocol with the following guidelines:

- A fully loaded heavy vehicle, which was of the same configuration as the most common HGVs on the road section, was used for calibration.
- 15 calibration runs were performed over the bridge WIM systems at each of the following speeds: 70 km/h, 80/km/h and 90 km/h.

The system accuracy requirement for each installation was set by PERS (see Table 1); the required accuracy was achieved on all 17 measuring locations.

Table 1 - Accuracy requirements

	Required accuracy
Single axle load	±15%
Load per axle group	±12%
Gross vehicle weight	±10%

Upon the completion of the calibration, each measuring location was monitored for any technical issues. The systems were then deinstalled and moved to another location. With five systems being used, 17 two-week measurements were completed in approximately two months.

4. Traffic Analysis Reports

A traffic analysis report was prepared for each of the measuring locations. These reports comprise the following topics:

- vehicle classification
- statistics on overloading
- hourly distribution of overloaded vehicles
- calculation of the shortening of the service life of the pavement based on actual ESAL values
- data analysis with proposals

The data from the bridge WIM system installed on the road section between the towns of Ruma and Šabac is presented in the following subchapter.

4.2 Sample Report: Ruma-Šabac[1]

The measurement on the road section Ruma-Šabac was performed between 14 and 27 October 2020. The bridge WIM system was installed on a 4-span concrete I-beam/deck bridge with 8 I-shape pre-stressed beams with an overall length of 102 m and individual span lengths of 25 m.

Figure 4 – Location of the installation of the bridge WIM system

The road section, where the measurement took place, is part of the IB21 main two-way road between the towns of Ruma and Šabac.

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[1] *Kulauzović and Beširević, 2020*

Figure 5 – Measuring location

Accuracy of the Measurement

According to the European WIM specifications (COST 323), class B accuracy was achieved at the measuring site; a detailed overview of the accuracy is presented in Table 2. The COST 323 accuracy requirement for a detailed traffic analysis and the collection of road design data is class C.

Table 2 – Accuracy of the measurement

	Lane 1	Lane 2
GVW	A(5)	A(5)
Group	A(5)	A(5)
Single	B(10)	A(5)

Traffic Analysis

The average daily heavy traffic detected by the bridge WIM system is presented in Table 3.

Table 3 – Classification overview of the traffic, daily average

Direction	Busses	Medium trucks	Heavy trucks	Semi/trailers	Other	Sum
Ruma-Šabac	37	106	17	456	1	617
Šabac-Ruma	37	106	17	495	0	655
Both directions	74	212	34	951	1	1272

On average, 951 trucks with trailers and semi-trailers were detected on the road section, while medium trucks (2-axle trucks with GVW up to 7 tons) form the second largest group of HGVs, with 212 vehicles per day. All in all, 1272 HGVs were detected on average by the bridge WIM system.

Traffic loading was observed to be significantly uneven between the lanes. Although the average number of HGVs per lane is similar, 72,5 % of average daily traffic loading was detected in the direction Šabac-Ruma (Table 4).

Table 4 – Average daily traffic loading

Direction	Busses	Medium trucks	Heavy trucks	Semi/trailers	Other	Sum
Ruma-Šabac	14,68 ESAL	0,64 ESAL	23,99 ESAL	274,69 ESAL	0,09 ESAL	314,1 ESAL
Šabac-Ruma	20,00 ESAL	0,51 ESAL	41,04 ESAL	765,33 ESAL	0,15 ESAL	827,0 ESAL
Overall	34,68 ESAL	1,15 ESAL	65,03 ESAL	1040,02 ESAL	0,24 ESAL	1141,1 ESAL

Upon a more detailed analysis, it was determined that these excess values of ESAL's were caused by heavy vehicles from a local construction site. 5-axle semi-trailer trucks with overloaded triple axles were especially problematic from the point of view of overloading. These vehicles were driving overloaded in one direction and returning empty, which was the reason for the disproportionality of the traffic loading over the lanes.

As it can be seen in Figure 5, a large number of heavy vehicles weighed around 50 t (the legal limit is 40 t). For the most part, these are the 5-axle semi-trailer trucks mentioned in the previous paragraph. Also problematic were 4-axle dumpster trucks whose GVW was in the range of 40 t to 46 t (with the legal limit for this class of vehicle being 32 t).

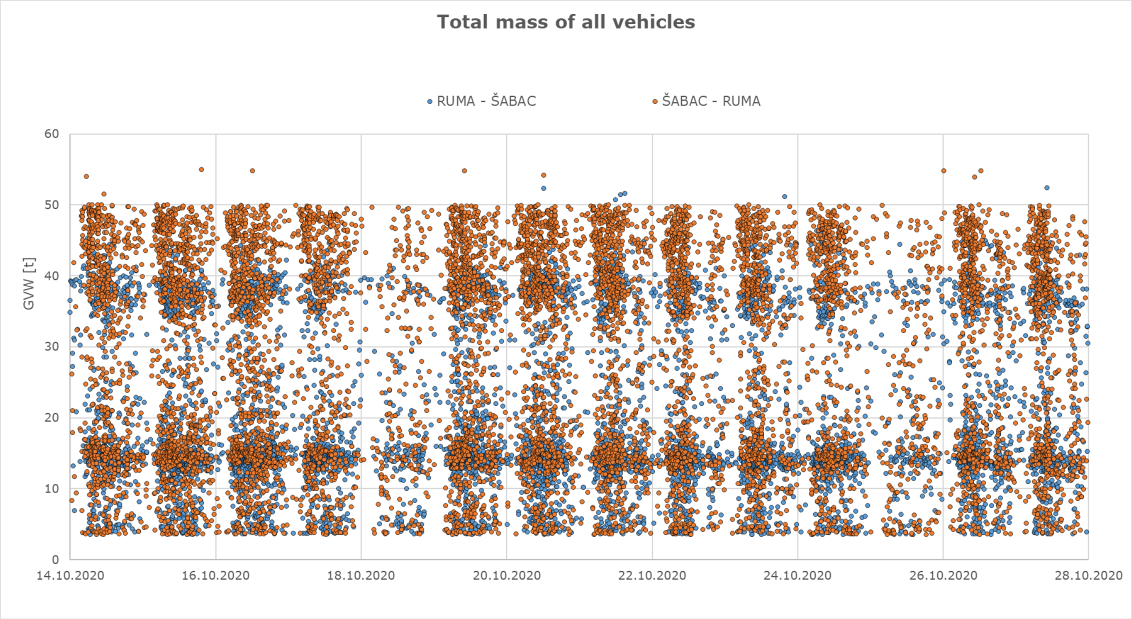

Figure 5 – Graphical presentation of GVW of individual vehicles

When it comes to axle loads, the histogram of axle overloading (Figure 6) shows that most single axles were overloaded by up to 0,5 t (2,19 %), dropping down to 0,37 % of overloaded single axles by more than 3 t. This represents typical transit traffic. Double axles are mostly overloaded in the range of "over 3 tons" (2,13 %).

Triple axles, on the other hand, were progressively more overloaded and most overloading occurred in the range of "over 3 tons" (58,72 % of all triple axles fall into this category). Triple-axle overloading represents local construction traffic with 5-axle dumpster semi-trailers.

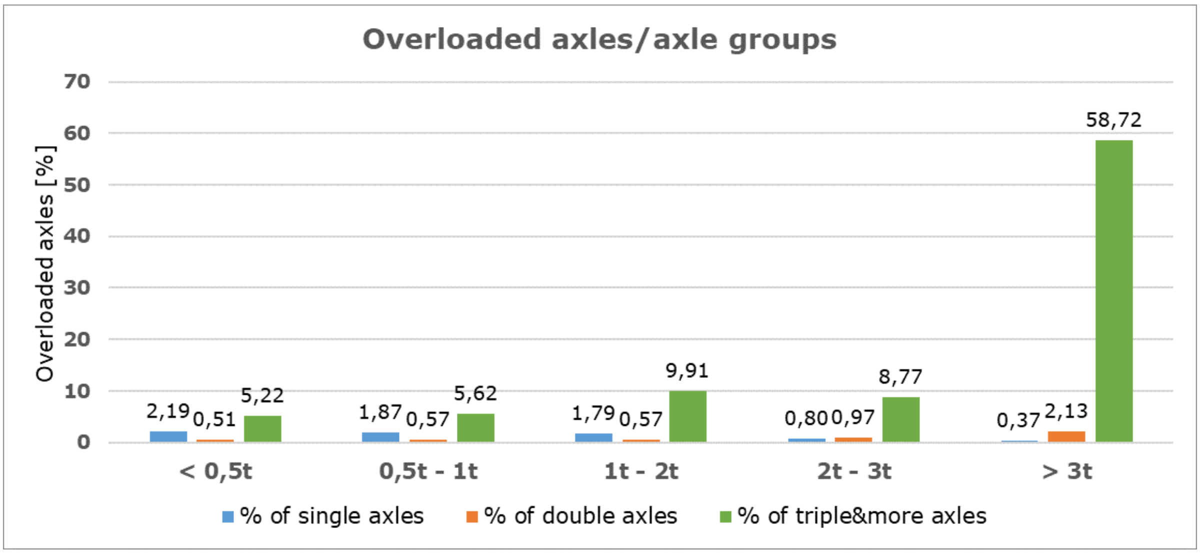

Figure 6 – Graphical presentation of GVW of individual vehicles

Based on the collected data, an estimation was made of the shortening of the service life of the road section. Due to excessive traffic loading, the service life of the pavement will be reduced by 5,8 years (Figure 7). With the 20-year design life of roads, this represents a 29 % reduction in the service life of the road section due to overloaded vehicles.

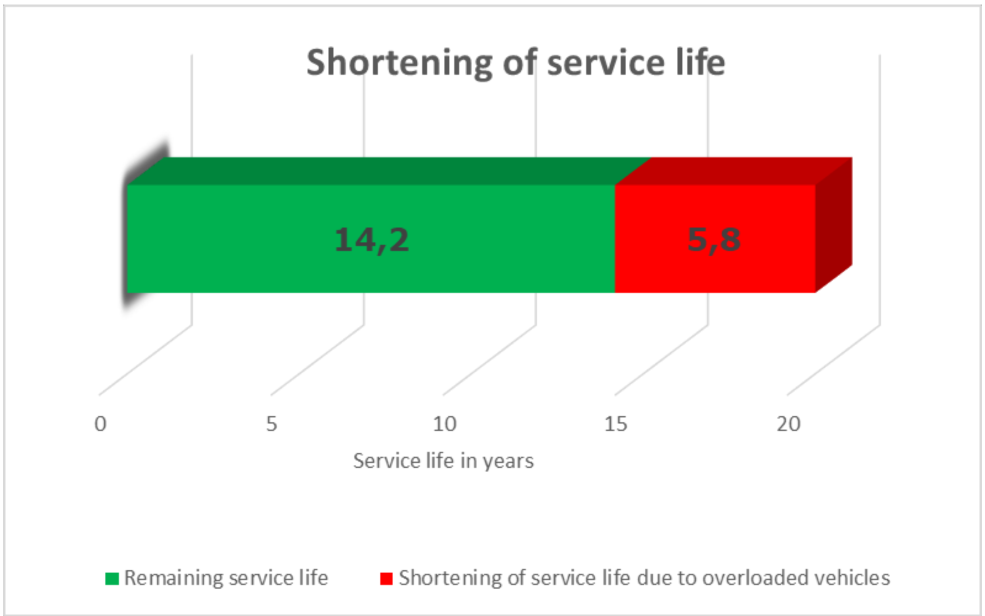

Figure 7 – Estimation of the remaining service life of the pavement

5. Conclusion

The article presented a novel strategy by the Public Enterprise Roads of Serbia (PERS), where the technological advantages of bridge WIM and road WIM systems are used for the maximum benefit of the infrastructure owners. Portable bridge WIM systems were used in a state-wide survey of traffic loading and other traffic statistics, while permanent road WIM stations and additional bridge WIM measurements are planned for the second phase, which is yet to be implemented.

Based on short-term bridge WIM measurements, traffic experts at PERS got an overview of the most problematic road sections of Serbia’s motorways and state roads. The gathered data can be used to plan enforcement policy, improve the design and maintenance of infrastructure, and plan further investments.

Based on the WIM data gathered on the road section Ruma-Šabac, we have shown that the amount of overloading on certain sections can be significant. This results in a substantial shortening of the service life of the pavement and consequent increased expenditures for infrastructure maintenance.

6. References

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