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Jong woo KIM, Young woo JUNG
UDNS Co., Ltd
A-517, U-TOWER Building, 767, Sinsu-ro, Suji-gu, Yongin-si, Gyeonggi-do, 16827 Republic of Korea
Ainura UTEBAYEVA, Zhuldyz KAMALIYEVA, Neil COLLINS, Dastan SARBASSOV, Janay SAGIN*, Raushan AMANZHLOVA
Nazarbayev University
Kabanbay Batyr Av. 53, Nur Sultan, 010000, Republic of Kazakhstan
**Corresponding author*. E-mail: zhanay.sagintayev@nu.edu.kz

HIGH-PERFORMANCE HIGH-SPEED WIM FOR SUSTAINABLE ROAD LOAD MONITORING USING GIS TECHNOLOGY

Summary. The increasing importance of better transport connectivity has indicated the need to develop high-speed road load monitoring technologies. The Belt and Road Initiative (BRI), Silk Road transportation programs considerable have developed the roads and highways networks in Kazakhstan and other Central Asian (CA) countries. Transportation services require proper maintenance and prompt track load monitoring. There is no holistic freight traffic management system that controls and monitors traffic flow in CA. A Weigh in Motion (WIM) technology can be used as an effective traffic management control system in the CA region. The WIM technology is designed to control axle and gross vehicle weight in motion. It has a wide range of applications, including pavement and bridge weight control, traffic legislation and state regulations. The WIM technology has advantages over conventional static weighing as it does not interrupt traffic flow by creating queues at monitoring stations. The WIM technology can be used not only as a weight control tool but also performs a comprehensive analysis of other traffic flow parameters. In cooperation with Korean UDNS experts with support from KAIA, we test the application of WIM in Nur-Sultan city, North of Kazakhstan, with Siberian-type cold weather. These works create much challenges and innovative approach to test sensors in the harsh environment, from the extreme cold to hot temperatures, with intensive dust distortions. Our Talapker WIM pilot test site was installed in September 2020, and it performs Gross Vehicle Weight (GVW) and Axle of Weight (AOW) analyses. The Talapker WIM High Speed (HS) sensors are capable of detecting different driving patterns, including everyday driving, acceleration or deceleration more than 10km/h/s and eccentric driving (partial contact with the platform to avoid excessive weighting). The pilot Talapker HS WIM site has demonstrated a positive effect on implementing WIM technology in Kazakhstan. Every 10th car passing through the WIM site registered as an overloaded vehicle by gross weighting, and every 5th car is considered overloaded by axle weighting. GIS-based location allocation analysis (LAA) performed in the given study provided an understanding of a practical implementation of WIM sensors. Taking into consideration different geographical data, the WIM site map was developed to reveal 43 suitable locations. Further improvements for the CA road network and their WIM demand points will be the focus of future research investigations.

1. INTRODUCTION

Trade relations have always served to expand economic cooperation between countries. The first model of a trade route, the Silk Road, became a connecting network that strengthened economic, cultural and political relations between East and West from the 2nd century BC to the 18th century. These days, the rising importance of better transport connectivity has indicated the need to develop new promising strategies. Launched in 2013, the Belt and Road Initiative (BRI, also known as One Belt, One Road) has become a new transcontinental system that aims at infrastructural development and the acceleration of the economic integration in the Eurasian countries along the route of the historic Silk Road [1]. Infrastructural connectivity and development have been considered one of the significant priorities of the BRI programme. Considerable attention is being paid to the development of new marine ports, airports, roads and highways. Kazakhstan and other Central Asian (CA) countries are major transit centres on the BRI network. The transportation and infrastructure issues in these states are of critical importance and demand new transportation management systems.

By providing improved logistics and supply chains, the new BRI corridor in CA will cause a significant increase in freight traffic volume between China and Europe. In this regard, it is essential to identify practical approaches to cope with freight traffic flow challenges. In CA countries, most roads, highways and railways are not designed for heavy traffic vehicles. Thus, it is more often the case that overloaded vehicles cross roads and highways not designed for such transport. As a result, transportation services face several challenges associated with overloaded vehicles. The problem of overloaded vehicles is one of the major concerns in pavement design engineering. Trucks exceeding weight limits damage the pavement structures. Pavement failure occurs due to different deterioration scenarios such as surface cracking, cutting and rutting from excessive load distributions. Studies demonstrate that an increase in the percentage of overloaded vehicles weight from 0% to 20% can reduce the fatigue life of asphalt pavements by up to 50% [2]. Thus, it is more often the case that pavement design does not perform as expected. Early replacement and improvement of pavements under heavy trucks are required. From an economic perspective, an overloaded vehicle can lead to significant repair and maintenance costs. More importantly, overloaded vehicles can be viewed as potential hazards for traffic security. Poor manoeuvrability, track instability and tyre overheating of overloaded vehicles can adversely affect road safety [3].

Currently, there is no holistic freight traffic management system that controls and monitors traffic flow. To reduce the number of overloaded vehicles and control weight parameters, a Weigh in Motion (WIM) technology can be used as an effective traffic management control system in the CA region. The WIM technology is designed to control axle and gross vehicle weight in motion. It has a wide range of applications, including pavement and bridge weight control, traffic legislation and state regulations. The WIM technology has advantages over conventional static weighing as it does not interrupt traffic flow by creating queues at monitoring stations. The WIM technology can be used not only as a weight control tool but also for a comprehensive analysis of other traffic flow parameters. Apart from its primary goals, that is, detecting the weight of vehicles, the WIM technology can also be considered a way used by enforcement police to collect penalties from overloaded vehicles.

The application of WIM in Kazakhstan has considerable potential as there are no specific weight control systems. Currently, state transportation agencies have developed regulations on the permissible mass of vehicles. However, these regulations are not being followed both by regulating agencies and by truck drivers. Currently, there is one WIM pilot site located in Talapker, Kostanay Region, Kazakhstan. The Talapker WIM site was installed in September 2020, and it performs Gross Vehicle Weight (GVW) and Axle of Weight (AOW) analyses. The Talapker WIM sensors are capable of detecting different driving patterns, including everyday driving, acceleration or deceleration more than 10km/h/s and eccentric driving (partial contact with the platform to avoid excessive weighting).

2. METHODOLOGY

The methodology reported in this paper represents a holistic approach of WIM technological implementation in Kazakhstan, including literature review of basic WIM parameters, types and components; spatial analysis of potential locations for WIM; and finally, data obtained from the existing Talapker WIM site in Kazakhstan.

2.1. Literature review

2.1.1. Working principle of WIM

The WIM system consists of several components: a data acquisition system, a communication system, a power supply station, sensors for load detection, inductive loop sensors used to measure vehicle parameters and cameras for automatic number plate recognition. The WIM system can provide information about the vehicle's gross and axle weight, structure and class of vehicles, number of axles, daily freight traffic flow and number of overloaded vehicles. These results can be used for pavement and bridge design and control, transportation policies to control congested traffic flow and transportation survey and data evaluation. One of the significant advantages of WIM is a direct enforcement policy (Fig. 1). Direct enforcement is an automatic process developed to control overloaded traffic flow on-site. Vehicle parameters are automatically recorded by the WIM system to evaluate them with permissible weight limits. If a vehicle is overloaded, enforcement authorities send official penalties to the truck owner or driver. Thus, the WIM system represents a fully automatic process for detecting overweight cases.

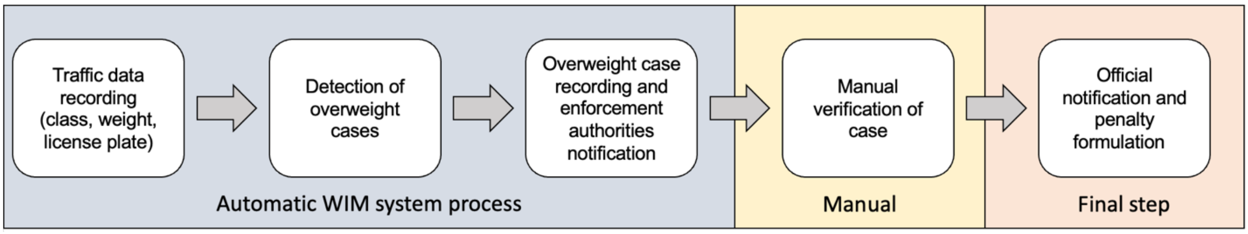

Fig. 1. The WIM system working procedure

2.1.2. Comparison of different weight-measuring technologies: static and dynamic (WIM)

For live load measurements, two different measuring systems can be used: static and dynamic. The dynamic measurement systems or Weight-in-Motion (WIM) technologies can detect and record vehicle parameters in motion. Static or stationary load-measuring systems can determine vehicle parameters in non-moving conditions or at very slow speeds.

The traditional method of load measurement on the roads used in Central Asia involves the use of the static measurement technique. The significant advantage of this method is the accuracy of the system and its applicability as a reference point for conducting experiments and calibrating weighing equipment. The stations are portable, and the carryover process and installations are simple, but the limitation is that the measurement of each axle should be performed separately, which is time-consuming. One measurement on average takes up to 45 minutes, and the process requires two people: the driver, to move the truck, and the operator, to monitor the process. Such time-consuming operations usually create traffic jams on the road [4].

Stationary scales called Truck Weigh Stations perform the load measurement of non-moving or slowly moving trucks. The stations are located off the road, and trucks need to exit the road to go through the scales. The main problem is that overloaded trucks can choose alternative routes so as not to have to go through the Truck Weigh Stations (ibid). In addition, if several trucks are already selected to pass by the weighting station, there is a possibility that during the measurement of those trucks, other overloaded vehicles will pass by and get unnoticed by the operators [3]. Therefore, static weight measuring is not reliable, it is complicated and takes a lot of time.

The alternative way is to apply weight-in-motion technology, which is a modern way of monitoring vehicle weight on roads. The sensors of the WIM system are built up inside the pavement and can determine the wheel load, axle load and configuration for trucks in motion. The technology has high efficiency, and is widely used worldwide [4].

2.1.3. Types of WIM

There are different types of WIM depending on specific site conditions and traffic flow. In general, WIM systems can be divided into 2 major groups: WIM depending on the vehicle speed and WIM depending on the site location.

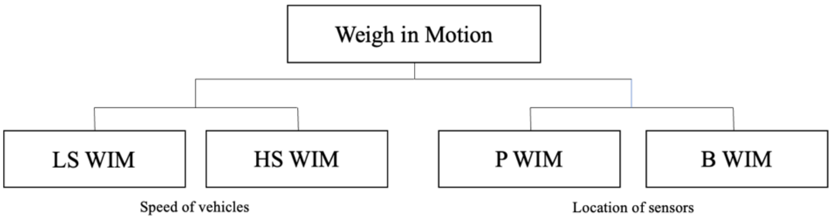

Fig. 2. Types of WIM systems

1. Low-speed WIM is used for traffic flow with a speed ranging from 5km/h to 10 km/h. LS WIM has a high accuracy level and it is used to determine vehicles' weights at control and inspection stations.
2. High-speed WIM is used for normal traffic conditions with different vehicle speed ranges. The major limitation of HS WIM is the reduced accuracy level due to increased speed. Weighting errors in HS WIM can reach as much as 15% for axle load and 5% for the gross load. Thus, HS WIM can be used only for the preselection process of potentially overloaded vehicles [5].
3. Pavement WIM sensors are located on pavement surfaces. This type is the most widely used WIM for traffic control management. Installation of sensors depends on the pavement design.
4. Bridge WIM sensors are located at bridges. B WIM sensors can measure not only vehicle parameters but also the deformation of bridges.

2.1.4. WIM for bridge structures

These days, bridges are considered as one of the critical structures to implement WIM technology. Different types of B WIMs can be installed either on the bridge's surface or underneath the bridge structure. B-WIM sensors located under the structure are called "nothing on the road" (NOR) sensors [7]. This development has demonstrated relative compatibility in comparison to conventional WIMs. NOR sensors provide a non-destructive method of installation, and, in contact with surface pavement sensors, it is not affected by the permanent loading of vehicles. As a result, NOR sensors have a longer service life. B-WIM installed underneath bridges is a portable system, and thus it can be relocated to different bridge types [6].

The main principle behind B WIM is measuring the structural response (deflection and deformation) of bridges' span under the traffic loading. The B WIM technology was first implemented by Moses in 1979 [8]. The Moses system consisted of two components: strain sensors installed on the bridge soffit and axle detectors. The results demonstrated that the bending moment is proportional to the product of the influence line (IL) ordinate and the magnitude of the vehicle load. The bending moment can then be converted into vehicles' axle weight.

2.1.5. WIM for pavement design

A typical area of WIM application is a pavement. P WIM is embedded into the pavement; therefore, it is essential to plan WIM installation before pavement design. The WIM systems can be equipped either by strip or plate sensors (Fig. 3). Vehicles pass sensors that indicate the load from the wheels. P WIM represents a direct method for vehicle weighting and provides full tyre imprinting.

The first WIM plate sensors were installed in the mid-1950s. The major advantage of bending plate sensors is direct contact with tyres, which can accurately measure axle and gross vehicle weight. However, plate sensors may cause significant pavement damage due to the development of holes and grooves.

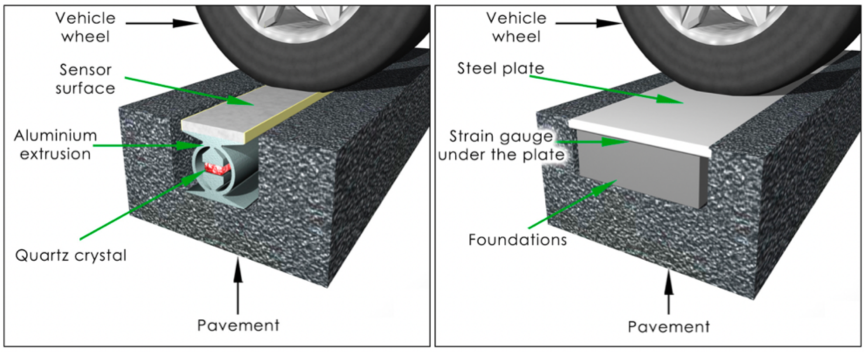

Fig. 3. Strip and bending plate WIM sensors [5]

The WIM strip sensors represent the preferred option in comparison to plate sensors. A strip sensor is in the form of a long narrow bar with a small cross-section mounted in a groove perpendicular to the lane direction. The strip sensors measure the pressure, strain or force variation when vehicle load is applied. Strip sensors are made of piezo-ceramic, piezo-quartz, piezo-polymer and fibreoptic components. Unlike plate sensors, strips do not allow direct calculation of axle or gross vehicle weight. It implements a signal processing algorithm that transforms data into acquisition stations [3].

2.2. Concept of pilot High-Speed WIM implementation in Talapker

The Talapker WIM station is the first test site in Kazakhstan, which was chosen to identify local features of freight traffic to solve the overloaded vehicle problem. The WIM sensors were installed in September 2020, and they are still working to date. From September 2020 to April 2021, 159,114 vehicles crossed the WIM platform on the Talapker site. A methodological analysis of vehicle flow in Talapker was conducted to evaluate Gross Vehicle Weight (GVW) and Axle of Weight (AOW) separately in relation to the total number of passing vehicles, their types, speed, time and type of driving.

Vehicle parameters are determined on-site and include the full range of vehicle flow data: time of crossing, license plate, speed, acceleration, gross and axle vehicle weight and type of vehicle (Fig. 4).

2.3. Spatial analysis using the Location Allocation algorithm

The methodology includes WIM location analysis using ArcGIS software. For this purpose, the location-allocation algorithm (LAA) was used to analyse the most suitable and effective sites for WIM installation. LAA represents the geospatial analysis designed to determine the optimal location for service provision. It is widely used in retail business and public institutions, e.g., schools, hospitals and police, to locate their branches across the city or specific area. The main principle of the algorithms involves connecting different facilities that provide services and their demand points to which services should be efficiently supplied, taking into account human, financial and time resources. The LAA was applied to identify suitable locations for WIM stations across the road network in Kazakhstan.

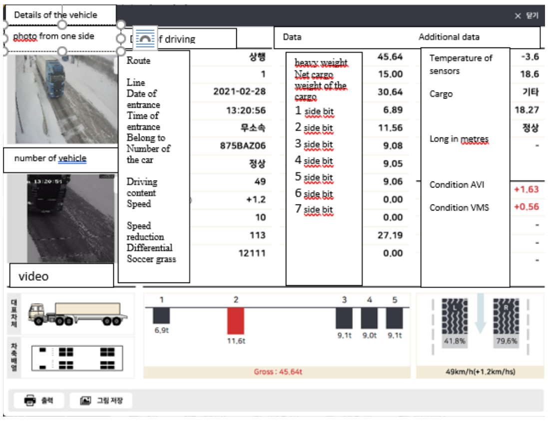

Fig. 4. Talapker WIM data acquisition

To conduct an analysis, it was necessary to identify demand points to which WIM sensors should be allocated. For this purpose, data were taken from the geofabrik.de online geospatial database for determining the country boundaries and road network. In this type of analysis, road branches were considered demand points to which WIM sensors are assigned. Amore elaborate investigation of WIM sensor distributions has revealed evasive flow capturing problems, referred to as locating law enforcement facilities drivers try to avoid any penalties imposed from overweighting or speeding. Taking into consideration extensive road networks, it is possible to suggest that overweight vehicles will avoid routes with WIM sensors installed on and, as a result, will follow “WIM-free” road branches. Therefore, it was necessary to cover the whole road network system in Kazakhstan, including minor road branches, to ensure that there is no evasive flow of traffic. However, from an economic point of view, it was reasonable to include only primary and secondary road types that have either international, state or regional significance. Another essential factor for this type of problem was population density. Input characteristics were assigned in such a manner to ensure that a higher number of WIM sensors are installed on areas with the highest density.

3. RESULTS

3.1. Talapkerpilot HS - WIM site results

According to the results obtained in the Talapker WIM site, the total number of passing vehicles differs significantly from month to month. As shown in the graph below, freight traffic flow substantially increases during the summer-autumn season. Although overloaded vehicles (GVW > 44 tons, AOW > 11 tons) represent a small proportion of the total number of passing vehicles, there is still a significant presence. For example, in October, the busiest traffic flow was a total of 24,423 vehicles passing (Fig. 5). Among the total number of passing vehicles in October, 1800 vehicles (7,37%) were recorded to have excessive gross vehicle weight and 3270 (13,39%) were recorded to have excessive axle vehicle weight.

Taking into consideration comparison of GVW and AOW distributions, it is seen that, although some of vehiclesmeet gross weight requirements, they might have an overloaded axle weight (Table 1).

Taking into account the types of vehicles that have excessive weight parameters in both GVW and AOW distributions, the following can be distinguished:

1. Single Unit 3 or more axle (Fig. 6).
2. Semitrailer 4 or more axle (Fig. 7).

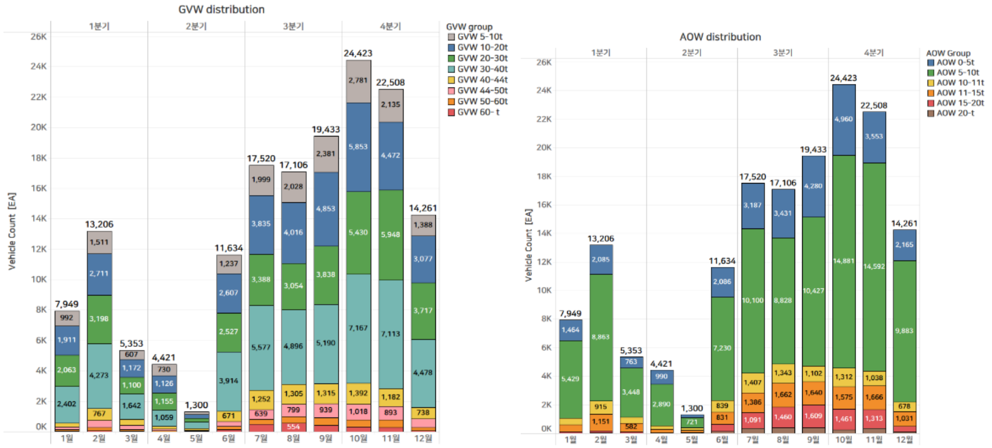

Fig. 5. Analysis of the total number of passing vehicles per month by GVW and AOW distributions

Table 1

Number and percentage of overloaded vehicles per month by GVW and AOW distributions

	GVW distribution			AOW distribution		
Month	Total number	Number of Overloaded	Percent of overloaded	Total number	Number of Overloaded	Percent of overloaded
1	7949	313	3,94	7949	593	7,46
2	13206	746	5,65	13206	1343	10,17
3	5353	408	7,62	5353	695	12,98
4	4421	165	3,73	4421	279	6,31
5	1300	108	8,31	1300	212	16,31
6	11634	678	5,83	11634	1479	12,71
7	17520	1469	8,38	17520	2826	16,13
8	17106	1807	10,56	17106	3504	20,48
9	19433	1856	9,55	19433	3624	18,65
10	24423	1800	7,37	24423	3270	13,39
11	22508	1658	7,37	22508	3325	14,77
12	14261	863	6,05	14261	1535	10,76

It was important to identify driving patterns to evaluate their effects on GVW and AOW distributions (Fig. 8). According to the results, the most common driving pattern in the normal GVW distribution is "normal" driving, while in the overloaded GVW distribution, drivers tend to follow an "out of lane" driving pattern. This feature can be explained by the fact that drivers prefer to evade weight control censors. An abnormal driving pattern refers to partial contact of the axle with the platform to avoid overloading. Unexpectedly, eccentric driving is present in the same portions both in normal and overloaded GVW distributions. Significantly higher cases of eccentric driving patterns were expected in the overloaded GVW distribution, where drivers cheat and "hide" overloading by having partial contact (Fig. 9).

In the normal AOW distribution, most drivers follow a normal driving pattern; about 18% have an eccentric pattern, and approximately 7% follow the "out of lane" pattern. As in normal AOW, in the overloaded AOW distribution, most drivers follow the typical driving pattern; about 40% and 15% have an "out of plane" or eccentric driving pattern.

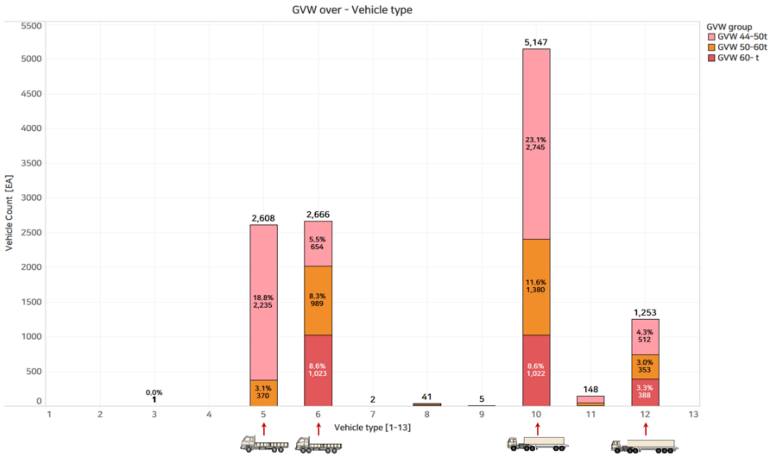

Fig. 6. Analysis of the GVW overloaded number of passing vehicles per type

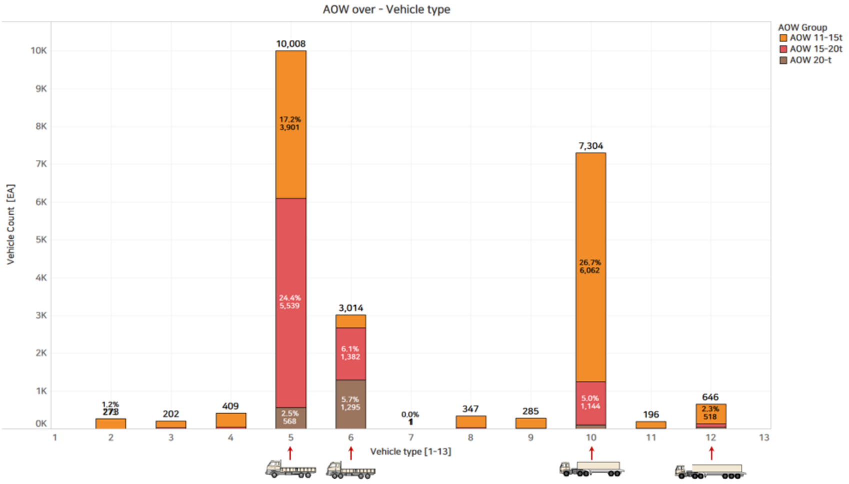

Fig. 7. Analysis of the AOW overloaded number of passing vehicles per type

In general, the results demonstrate that the normal driving pattern is the standard option. Since the Talapker site is an HS-WIM station, drivers are not required to reduce speed while passing the platform. In this respect, the acceleration or deceleration pattern is insignificant. It is also important to notice that in both overloaded GVW and AOW distributions, has a significant portion of overloaded vehicles.

Results from the pilot Talapker HS WIM site demonstrated the need to adopt the WIM technology in Kazakhstan. According to the results, up to 10% and up to 20% of passing vehicles have overloaded gross vehicle weight and axle vehicle weights, respectively. The significant scale of the problem of overloaded vehicles can be considered a major problem for road conditions and safety.

3.2. Spatial analysis results

The results of LAA have revealed 132 WIM candidate stations for locating sensors across the boundaries of Kazakhstan. A manual analysis was performed to avoid any excessive locations with no reasonable necessity to place WIM sensors: minor road branches, repeated sensors on the same road branch. As a result, only 43 WIM site points were chosen as a final solution to the problem. According to LAA, WIM stations were assigned to international M32, M36, M38, M51, E30, E38 and E40 routes; state A1, A2, A3, A13, A16, A17, A18, A21, A22, A24, A27, A28, A33, A351, A356 andA358; and regional P24, P87, R18, R174, R265 andR335. The final location of the WIM sensors in the road network of Kazakhstan can be seen below (Fig. 10).

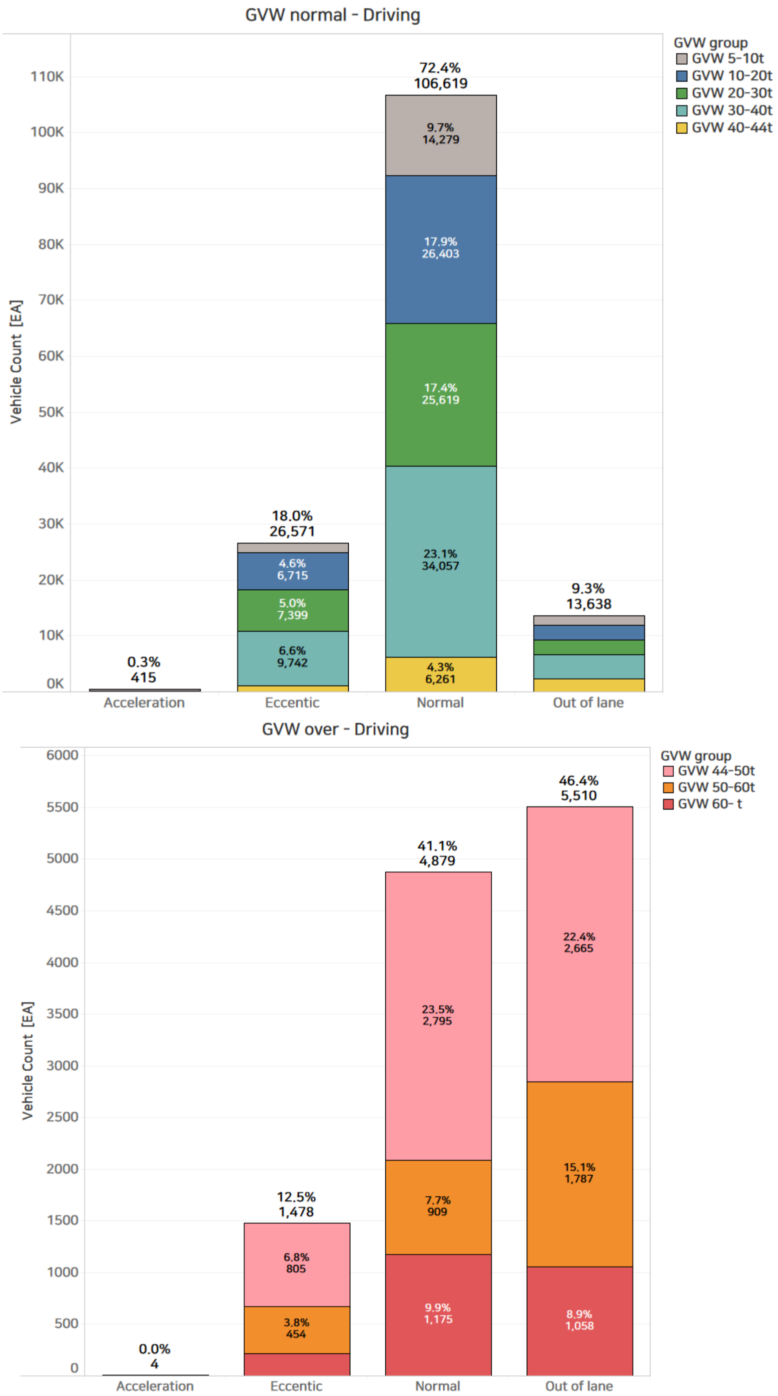

Fig. 8. Analysis of the GVW normal and overloaded number of total vehicles per driving pattern

Table 2 below demonstrates the proposed geospatial coordinates for locating WIM sensors, the road name, the state region where sensors are located and cities that are connected by road. As can be seen, the majority of WIM sensors are located on roads that connect major cities or state regions.

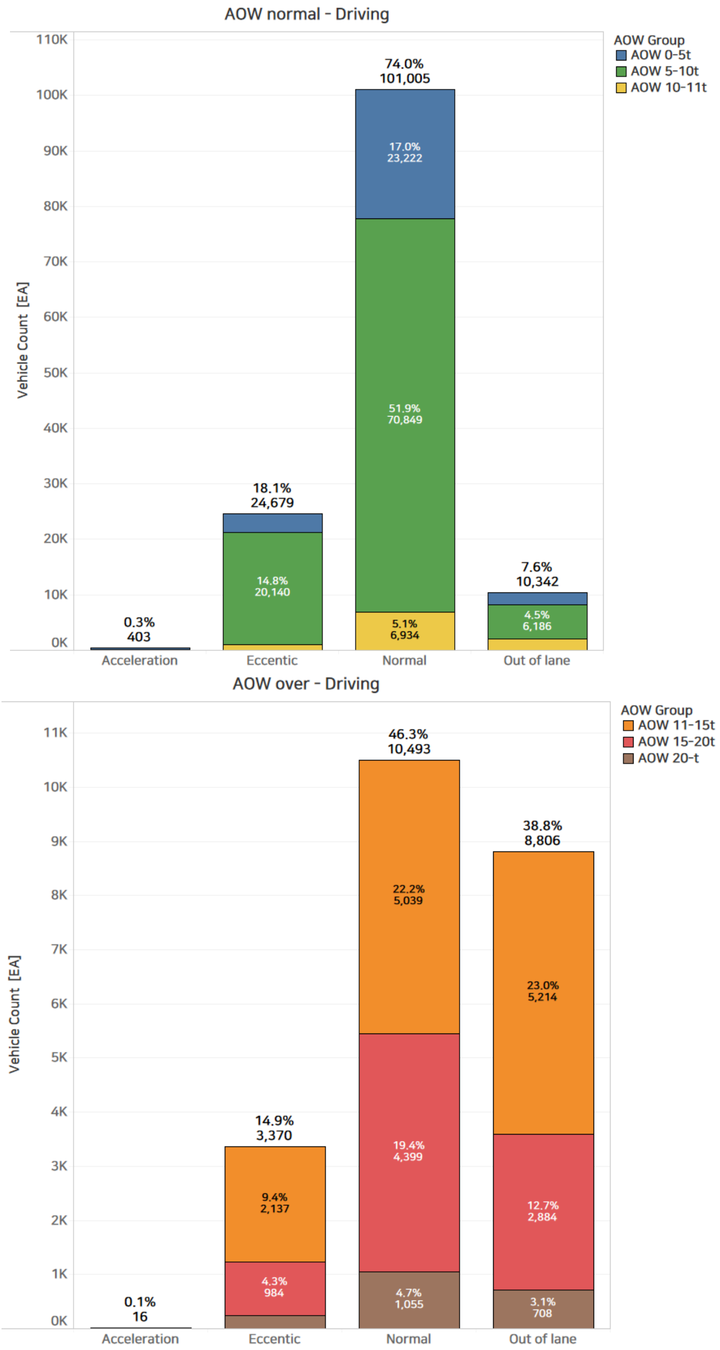

Fig. 9. Analysis of the AOW normal and overloaded number of total vehicles per driving pattern

There are several limitations to the proposed solution. To conduct a more comprehensive analysis, it is necessary to understand daily and monthly traffic flow. These findings could be used to investigate the number and frequency of freight vehicles on the road to perform a more detailed location–allocation analysis. For example, roads with the highest freight traffic flow should be equipped with a higher number of WIM sensors, whereas there could be roads that do not require any sensors. However, since there are no databases for traffic flow in Kazakhstan, only primary geographical data were collected, such as country boundaries, road network, type of road and population density. Further improvements can be made in collecting traffic data in Kazakhstan.

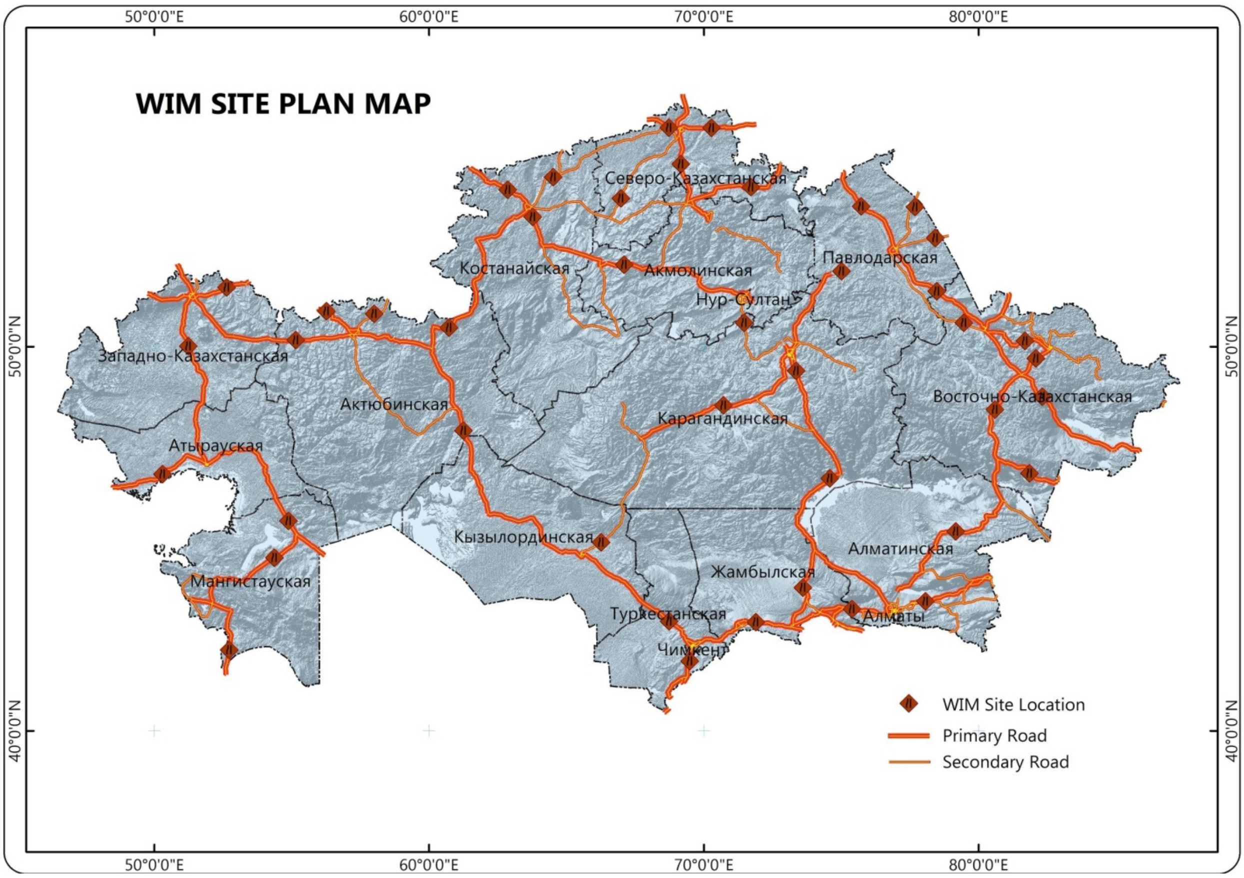

Fig. 10. The WIM site plan

The research findings can be used as a practical proposal to distribute WIM sensors in Kazakhstan. However, it is crucial to perform an objective case analysis of the most marketable road branches with the highest freight traffic flow.

4. CONCLUSIONS

The WIM system is considered a beneficial tool to control traffic management in Kazakhstan. By providing a fully automatic procedure of traffic weighting, the WIM has the potential to cope with overweighing. This insight, as a result, will markedly enhance road safety as well as bridge and pavement stability. The results of this research have demonstrated the comparative advantage of WIM technology over the conventional static weighing procedure. It is believed that with the new BRI initiative, freight traffic management in Kazakhstan will face significant challenges. Thus, WIM can be viewed as an efficient traffic management control system.

The pilot Talapker HS WIM site has demonstrated a positive effect on implementing WIM technology in Kazakhstan. Every 10th car passing through the WIM site registered as an overloaded vehicle by gross weighting, and every 5th car is considered overloaded by axle weighting. The Talapker WIM site provides additional services, including recording of vehicles speed, type and time.

Table 2

The WIM location-allocation algorithms result in Kazakhstan

№	Region	Latitude	Longitude	Road	
1	West Kazakhstan	51°16'11.4"N	52°13'51.1"E	R 335	Uralsk – Orenburg, RU
2		49°59'16.7"N	51°15'09.7"E	A 28	Uralsk – Atyrau
3	Atyrau	46°47'31.0"N	50°12'11.7"E	A 27	Atyrau – Astrakhan
4	Mangystau	45°54'58.7"N	54°41'13.5"E	E 40	Atyrau – Nukus, UZ
5		44°47'11.5"N	54°32'40.5"E	A 33	Aktau – Beyneu
6		42°00'22.8"N	52°40'35.9"E	R 18	Aktau – Turkmenbashi, TM
7	Aktobe	50°08'31.9"N	54°46'12.5"E	E 38	Aktobe – Uralsk
8		50°39'29.3"N	56°34'45.5"E	A 24	Aktobe – Orenburg, RU
9		50°33'24.1"N	57°32'21.6"E	P 87	Aktobe – Orsk, RU
10		48°00'48.3"N	61°12'16.6"E	E 38; M 32	Aktobe – Kyzylorda
11		50°29'01.2"N	60°50'31.6"E	A 22	Aktobe – Kostanay
12	Kostanay	53°30'28.1"N	63°03'38.6"E	M 36	Kostanay – Chelyabinsk, RU
13		52°58'16.4"N	63°46'35.6"E	R 265	Kostanay – Arkalyk
14		54°09'12.6"N	65°28'03.5"E	A 21	Kostanay – Petropavlovsk
15	North Kazakhstan	53°22'40.1"N	66°58'26.5"E	A 16	Petropavlovsk – Jezkazgan
16		54°55'11.3"N	68°43'40.6"E	E 30 M 51	Petropavlovsk – Chelyabinsk, RU
17		54°54'54.2"N	69°48'57.5"E	M 51	Petropavlovsk – Omsk, RU
18		54°22'17.1"N	69°10'14.7"E	A 1	Petropavlovsk – Kokshetau
19		53°39'45.0"N	70°55'21.5"E	A 13	Kokshetau – Kishkenekol
20	Akmola	51°51'53.9"N	67°34'28.3"E	M 36	Nur Sultan – Kostanay
21		50°59'30.5"N	71°54'26.9"E	M 36	Nur Sultan – Karaganda
22	Pavlodar	51°32'44.9"N	74°21'43.9"E	A 17	Pavlodar – Karaganda
23		53°11'06.6"N	75°46'46.9"E	M38; E 127	Pavlodar – Omsk, RU
24		53°07'22.0"N	77°34'05.7"E	A 17	Pavlodar – KZ/RU border
25		52°24'38.8"N	77°40'48.1"E	A 18	Pavlodar – KZ/RU border
26		51°23'42.4"N	78°18'09.1"E	M 38	Pavlodar – Semey
27	East Kazakhstan	50°31'49.7"N	79°31'05.4"E	R 174	Semey
28		50°06'46.8"N	81°35'14.6"E	P 24	Semey – Ust-Kamenogorsk
29		49°34'02.4"N	81°51'47.5"E	A 3	Ust-Kamenogorsk – Kalbatau
30		49°09'34.0"N	81°09'22.5"E	A 3	Kalbatau – Ayagoz
31		49°05'17.1"N	81°57'53.0"E	M 38	Semey – KZ/CN border
32		46°57'21.0"N	81°47'38.3"E	A 356	Ayagoz
33	Karaganda	49°31'31.2"N	73°17'19.7"E	M 36	Karaganda – Balkhash
34		46°41'54.5"N	74°26'40.6"E	M 36	Balkhash – Almaty
35		48°35'25.8"N	70°36'41.1"E	A 17	Karaganda – Jezkazgan
36	Kyzylorda	45°17'14.2"N	66°32'22.5"E	A 17	Kyzylorda – Jezkazgan
37	Turkestan	43°05'04.0"N	68°38'50.6"E	E38; M 32	Shymkent – Turkestan
38		41°50'10.1"N	69°24'14.9"E	A 2	Shymkent – KZ/UZ border
39	Zhambyl	42°58'31.1"N	72°23'52.2"E	A 2	Taraz – Almaty
40		44°16'07.9"N	73°48'19.3"E	A 358	Taraz – Balkhash
41	Taldykorgan	43°19'40.9"N	75°40'05.5"E	A 2	Almaty – Taraz
42		44°35'29.6"N	77°57'12.2"E	A 3	Almaty – Taldykorgan
43		43°30'26.3"N	77°33'21.1"E	A 351	Almaty – KZ/CN border

Location allocation analysis performed in the given study provided an understanding of a practical implementation of WIM sensors. Taking into consideration different geographical data, the WIM site map was developed to reveal suitable locations. This finding can play a beneficial role in the decision-making process of determining possible locations for WIM sensors. The final solution of LAA has demonstrated 43 locations for WIM sensors, covering all state regions and major roads in Kazakhstan. Installation of WIM sensors in Kazakhstan will have a positive effect by decreasing the number of overweight trucks and subsequent collection of fines imposed by law enforcement policies. The collected fines can be used to maintain WIM sensors and road pavements.

Further improvements can be made to investigate the whole Central Asian Road network and their WIM demand points in a frame of development of the BRI corridor. It is also suggested to conduct a statistical analysis of traffic flow to reveal major freight traffic trends in road networks.

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