**Abstract.** The purpose of this article is to develop an automated system for monitoring the weight and size indicators of cars on the highways of Kazakhstan. The advantages of automated weighing systems of transport systems used on the world's highways are analyzed. The hardware architecture of the system with remote processing of weight norms by motor vehicles has been developed. The effectiveness of the use of stationary posts for monitoring weight indicators and measuring the overall dimensions of vehicles is substantiated. As a result of the study, a comparative analysis of advanced technologies for weighing trucks in traffic was performed.

**Keywords:** motor vehicles, highways, weight standards, transport control post, weighing technology.

**Introduction.**

It is known that every overloaded vehicle leads to an increase in vehicle wear by 57%. Exceeding the permissible axle load leads to an increase in damage to highways: 10% exceeding the axle load limit leads to an increase in damage to the roadway by 30-50%, as a result of which the service life of highways is shortened, the costs associated with repair and reconstruction of highways increase.

In addition, the main problem in the field of ensuring the safety of highways is the presence of corruption offenses, as well as the facts of uncontrolled passage of vehicles with violations. In this regard, in order to solve these issues, it is necessary to carry out work on automating the procedure for weighing vehicles at transport control posts [1].

We have investigated the prospects of using an automated weighing system for motor vehicles in the Republic of Kazakhstan.

The introduction of an automated measuring system allows you to achieve certain advantages, namely:

1) At the entrance to the posts, carry out automatic weighing of vehicles in motion with identification of State registration plates (at a speed of 60-90 km/h);
2) Increase cargo flow, speed of passage (up to 90 km/h);
3) Minimize the number of contacts between drivers and traffic control inspectors.
4) At the same time, an increase in charges for the passage of motor vehicles on toll roads of the Republic of Kazakhstan is expected.

As a result, the speed of freight traffic along the main international transport corridors of Kazakhstan will increase to 20%.

The main requirements for automated information systems were stated [2]:

**IMPROVEMENT OF THE WEIGHT AND DIMENSIONAL CONTROL OF MOTOR VEHICLES ON THE HIGHWAYS OF THE REPUBLIC OF KAZAKHSTAN**

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1) the territorial distribution of a hierarchical system with a single control and control center, the openness of the architecture of automated information systems with the possibility of integrating information systems of regions and departments into it;

2) using the latest achievements in the field of information technology, building data processing, storage and activation centers;

3) scaling of the functionality of automated information systems to all levels of management; reliability and integrity of the information received;

4) protection against unauthorized access to information;

5) modern equipment that ensures high efficiency and safety of the system;

6) fault tolerance and disaster tolerance of automated information systems;

7) Ease of installation, support and staff training;

8) automation of system infrastructure management.

Currently, the existing transport control posts are working to identify overloaded vehicles. The automated vehicle weighing system allows you to provide a wide range of information services. Its main functions include the implementation of [3, 4]:

- control over ensuring the safe operation of vehicles;
- control over the passage of motor vehicles through the territory of the Republic of Kazakhstan, including compliance by domestic and foreign carriers with the permissible overall and weight parameters of motor vehicles installed on the territory of the Republic of Kazakhstan;
- control over ensuring the safety of the roadway of the highway network on which they are stationed;
- registration of temporary entry of foreign vehicles;
- statistical reporting of violations of traffic safety requirements;
- control over the observance by drivers of motor vehicles of the established work and rest regime when transporting passengers and cargo.

**Materials and Methods.**

After analyzing the use of automatic systems for determining the weight and size parameters of cars, a solution based on the Measure-in-Motion vehicle detector, from the Slovak company Betamont, was proposed. The solution also provides all the necessary functionality for the organization of a transport control post with the possibility of pre-weighing [5].

Identification of excess permissible masses by means of a vehicle detector "Measure-in-Motion" gives:

1) dynamic weighing of vehicles;
2) measuring the height of vehicles;
3) measuring the speed of vehicles;
4) camera system with vehicle registration plate identification;
5) shooting and imaging images of overloaded vehicles of non-standard sizes;
6) image and filming of vehicles exceeding the speed limit;
7) informing the driver about violations and stop requirements.

"Measure-in-Motion" records the passage of vehicles with a certain selection of overloaded vehicles and vehicles of non-standard dimensions in all traffic lanes while driving without speed limits on a road or motorway. Information about the passage of a critical vehicle is provided in the form of a drawing with additional identification data: the date and time of the vehicle's passage, the registration number in the form of text and a detailed drawing, information about exceedances (weight, dimensions, speed) [4].
The detector is combined with a system of dynamic weighing and measuring the dimensions of vehicles, a camera speed measurement system. A typical image of the control arch is shown in Figure 1, a typical MiM solution is shown in Figure 2.

Traffic flow control system with the "Measurement in motion" function due to a change in the trajectory of movement [6]:
- identification of overloaded vehicles in the traffic flow using WIM detectors;
- automatic recognition of vehicle license plates;
- recording data about such a vehicle (photo, recognized vehicle registration number, date, time, approximate weight of the vehicle, direction of movement);
- informing the driver of the vehicle using VMS variable information signs;
- withdrawal of the vehicle from the general traffic flow;
- the direction of the vehicle for weighing on the control scales;
- collection of statistical data on vehicles and traffic flows in both directions of movement.

The system meets the requirements for measuring the weight of vehicles in motion with the "Measure-in-Motion" detectors. The hardware architecture of the system with remote violation processing is shown in Figure 3.
Such a system consists of the following devices:

1. The equipment of the automated control post, which includes [7]:
   a) piezoelectric weighing sensors mounted in the roadbed;
   b) inductive loops of the presence of vehicles mounted in the road surface;
   c) identification cameras of State registration plates mounted on poles with an upper outrigger support console mounted on bolted connections for dismantling in case of passage of non-dimensional cargo;
   d) a WiM processor installed in a climate cabinet;
   e) an industrial data processing computer installed in a climate cabinet;
   f) a climate cabinet that ensures operation at a set temperature at an external temperature from -40 to + 50 °C;
   g) a satellite data transmission terminal;
   h) a pole with an upper remote console for mounting identification cameras of State registration license plates;
   i) an information board of variable information.

2. Data Processing Center equipment (Automated operator workplace, notification preparation automation systems, etc.), includes [7]:
   a) Automated workplace of operators;
   b) notification preparation automation equipment.

3. Remote hosting (server part). The information component of the system of automated transport control posts, with remote processing of violations, consists of [7]:
   a) subsystems of information support of the Data Processing Center and management of the automated post;
   b) weight and speed control subsystems;
   c) video surveillance and vehicle classification subsystems;
   d) the subsystem of information and data transmission.

The MiM control system collects information from WIM detectors and video surveillance cameras, controls traffic through traffic signs with changing VMS information, and transmits the necessary data to the control post. The system integrates with other systems via GSM/GPRS, TCP/IP, RS232, RS485 and WiFi. Data and video information are processed using an industrial computer (server).

When a vehicle passes through the elements of the dynamic weighing system, the vehicle data is automatically recorded, which are generated in the form of a report and sent to the control post. If, during the weighing process, the fact of overloading of the vehicle is detected, information appears on the information board indicating the state registration number of the car and the instruction to continue driving to a stationary transport control post to carry out a check weighing operation [4].
Figure 3 - Hardware architecture of the system with remote violation processing

At a stationary transport control post, a control weighing of the vehicle is performed, the degree of congestion is determined, the dimensions of the transport are measured, exhaust gases are checked and tachograph readings are taken to determine the mode of work and rest. An employee of the transport control post draws up a protocol, indicating all registration data of the vehicle and the amount of the fine. The vehicle, until the violation is eliminated and the fine is paid, is sent to the impound lot for a period of 1 to 10 days.

Variable information signs (VDI) play a crucial role in the organization of traffic safety. VDI displays text messages for drivers about road and weather conditions, repairs. They will promptly warn the driver about traffic jams and accidents. Such information assistants have already been installed everywhere in the world. The RFI is used for the following purposes [2]:

1) notifying drivers of cargo vehicles about approaching the high-speed weighing site, about a previously detected overload and the need to undergo a control weighing;

2) informing the inspector about the need to stop the cargo vehicle and carry out a control weighing.

Results and Discussion.

In motion weighing systems, constant and variable information displays (VMS) are used to inform. The VMS display of variable information (LEDs – red, green) allows you to reject an
identified vehicle from the general flow and direct it to a stop area. The symbols and text of the
vehicle registration number, which are depicted on a variable road sign, inform the driver of the
detected vehicle and give him a command about the direction of his further movement. Variable
information signs can be included in a comprehensive solution of pre-weighing systems, or
supplied by individual companies. Universal LED variable information display, designed to work
as part of road Automated control systems, which are designed to inform traffic participants about
the situation on the road in the form of text messages, etc. [8]. Examples of the use of information
technology are shown in Figure 4.

Figure 4 - Examples of the use of information technology

Technologies for recognizing state registration plates. Currently, there are more than half
a billion cars on the roads in the world. All these vehicles have a unique identification number as
the main identification mark.

The vehicle identification number is actually a registration number that gives the legal right
to participate in road traffic.

The basis of any system of identification of a state license plate is the recognition
algorithms used. The qualifications of developers in the field of modern higher mathematics,
image processing, programming and program optimization technologies, as well as the presence
of significant work experience - all these factors determine the characteristics of the system, such
as: the probability of recognition, processing speed, the ability to recognize different types of
license plates, the ability to work with images of different quality. General principles of
recognition system algorithms: identification of the intended areas of the license plate,
identification of the type of license plate, character recognition, formation of the resulting number
[9].

Automatic License Plate Recognition (ALPR) is literally the ability to automatically
highlight car license plate characters from an image. Essentially, it consists of a frame capture
mechanism that has the ability to capture an image, search for the location of a number in the
image, and then highlight characters using optical character recognition (OCR) tools that convert
pixels into readable digits.

In cargo transportation and logistics, it is especially important to weigh transport, determine
the weight of cargo transported by road or rail, as well as determine whether the load of the vehicle
meets established standards. Comparative indicators of weighing technologies are shown in Table
1.
Table 1 - Comparison of weighing technologies

<table>
<thead>
<tr>
<th>Name</th>
<th>«+»</th>
<th>«-»</th>
<th>Additionally</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>By type of installation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile</td>
<td>Ease of deployment and operation</td>
<td>The measurement error is high, it is necessary to look for a relatively flat place to deploy</td>
<td>They are used to organize weighing that is not tied to any territory or road section.</td>
<td>Since the posts are stationary (linked to a specific territory), the most optimal option is a stationary type of installation</td>
</tr>
<tr>
<td>Stationary</td>
<td>Higher accuracy compared to the mobile version</td>
<td>Additional construction structures are needed to protect against adverse weather conditions, pumping water from the trenches of the installation</td>
<td>These scales involve the construction of lifting platforms and trenches for them of considerable size in the case of static weighing.</td>
<td></td>
</tr>
<tr>
<td><strong>Type of weighing</strong></td>
<td></td>
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<tr>
<td>Static weighing</td>
<td>The highest measurement accuracy</td>
<td>A significant area is required for the installation of lifting platforms. Dependence on weather conditions.</td>
<td></td>
<td>Since it is necessary to ensure traffic control without stopping the vehicle, dynamic weighing is the best option.</td>
</tr>
<tr>
<td>Weighing in motion</td>
<td>The ability to weigh vehicles without stopping, measure speed, classify vehicles by axes in integrated systems.</td>
<td>The measurement error increases due to the movement of vehicles. Dependence on weather conditions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dynamic weighing</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Strain gauges</td>
<td>Maximum accuracy among in-motion weighing systems</td>
<td>Relatively low weighing speed up to 10 km/h</td>
<td>The lifting plate is of small size.</td>
<td>It is advisable to use piezoelectric circuits, as only this technology can provide weighing in the desired range.</td>
</tr>
<tr>
<td>Piezoelectric circuits</td>
<td>They provide the possibility of weighing at</td>
<td>High margin of error from 5% and above</td>
<td>Such solutions are used to count traffic, filter</td>
<td></td>
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</table>
Additionally, the maximum speed among weighing systems in motion up to 120 km/h is vehicles by weight, speed, i.e. they are used in vehicle pre-control systems without stopping the flow.

The assessment of the upcoming costs and results is carried out within the billing period. The duration of the billing period depends on many factors: the duration of the investment period, the service life of buildings and structures, the main technological equipment, the accuracy of technical and economic information for the coming years, the time to achieve the planned profit or payback period for capital investments, the duration of construction, investor requirements, etc. In our case, the calculation period in the Republic of Kazakhstan is 20 years, since the terms of major road repairs currently amount to 15 years, and after the implementation of the project will be 20 years [10].

The revenue side is usually taken as savings on road repairs, which is formed as a result of reducing road wear and increasing the repair period.

To calculate the strength of road surfaces and check the stability of the roadbed, the load on the single most loaded axle of a two-axle car was assumed during the feasibility study: 100 kN - for roads of categories I-IV; 60 kN - for roads of category V.

Data from the American Association of State Highway and Transportation Officials (AASHTO) are used as calculated dependencies to determine the degree of wear reduction and, accordingly, the degree of reduction in repair costs. These data determine that the equivalent coefficient of wear of road surfaces under the influence of vehicles with different axial loads compared to the axle pressure of 60 kN (Table 2).

### Table 2 - The coefficients of wear of road clothes under the influence of cars

<table>
<thead>
<tr>
<th>Axial load, kN</th>
<th>Equivalent wear factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>80</td>
<td>1.6</td>
</tr>
<tr>
<td>100</td>
<td>2.9</td>
</tr>
<tr>
<td>130</td>
<td>6</td>
</tr>
</tbody>
</table>

**Conclusion.**

The main function of the automated system is to measure the vertical forces of the axes of vehicles on the roadway and their total mass in motion. With the help of the automated WIM control system, it is possible to simplify the process of checking vehicles, save a sufficient amount of time, and minimize the funds spent on repairing highways associated with exceeding permissible axial loads.

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REFERENCES


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