НОВАЯ НАУКА
Международный центр научного партнерства

R. M. Aliev, M. M. Aliev, E. T. Tokhirov

IMPROVEMENT SENSORS OF SYSTEM CROSSING SIGNALIZATION AND REDUCTION DELAYS AT LEVEL CROSSINGS

Монография

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The monography explores models and algorithms for improving the control sensors of railway crossing signaling systems. In the high and low isolation resistance zones, promising wireless rail circuits are provided for railway crossing signals, and additional zones for shunting the control sensors by different methods of connecting the receivers have been identified. Methods and models for determining analytical expressions for the analysis and synthesis of control sensors in basic operating modes were considered. Mathematical models based on non-current rail circuits have been developed to determine the speed at which high-speed and high-speed trains approach the railway crossing. The vehicle was stopped at a railway crossing.

The monography is intended for use by scientific and engineering personnel, the operation, design and construction of automation systems and devices of the intersection, as well as for use by university students and students of railway transport colleges.

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ОГЛАВЛЕНИЕ

INTRODUCTION

One of the most important tasks in improving the capacity and safety of railway crossings in the world is the development of its infrastructure and intelligent information and communication sensor models, the study of structural principles and their application in practice. Particular attention is paid to reducing the likelihood of accidents, strict regulation and control of traffic rules and road design standards, expansion of safety measures or high technical equipment. It is important that the equipment at the intersections of highways and railways facilitate the management and road users through their activities.

Long-term closures of railway crossings in densely populated cities, frequent traffic jams and, consequently, reduced or stopped train speeds, increased waiting times for vehicles and passengers, scientific research on these problems is underway as it has led to a decline in overall efficiency. In this regard, the development of models and algorithms for the study of sensors to monitor the condition of sections approaching train crossings in order to eliminate system deficiencies and hazards is considered a topical issue today.

Rail is the most effective way to meet the transportation needs of megacities around the world. At intersections in densely populated cities, at railway crossings (railway crossings or crossings) there is a specific vulnerability to congestion. Especially near intersections, in the movement of pedestrian crossings, it creates a lot of collisions for trains and pedestrians. These crossings will reduce the speed of traffic and trains, increase travel time, congestion and reduce the overall efficiency of the railway network.

The country is taking comprehensive measures to deepen structural changes, modernize and diversify the leading sectors of the national economy, increase its competitiveness, ensure the balance and stability of the national economy, improve systems such as industry and services. The Action Strategy for the further development of the Republic of Uzbekistan for 2017-2021, including «....... technical and technological renewal, implementation of production, transport and communication and social infrastructure projects [1], ... further development of road and transport infrastructure, introduction of information and communication technologies in the economy, social sphere, management system». Functions are defined. In carrying out these tasks, one of the most important issues is the development of methods and algorithms for improving the control sensors of signaling control systems at railway crossings.

As of 2012, there were 7.3 billion people on earth. It is estimated that there could be one million intersections in the world, and that more than 6,000 deaths (there are large differences across countries) occur at railway crossings each year. According to the World Health Organization (WHO), more than one million people die on the roads worldwide each year, 90 percent of them in low- and middle-income countries. WHO accounts for 1-2% of the country's gross domestic product (in high-income countries). The world's population is growing rapidly, especially in poor or developing countries, and will continue to do so in the future. At the same time, the significant growth of road and rail transport has led to an increase in the number of long waits for vehicles due to the passage of trains at railway crossings. Therefore, we should expect the interconnection of these two modes of transport to be a source of increasing concentration in balancing the needs of society, the economy and security. Extensive research is being conducted to address these issues.

As a result of scientific research around the world, foreign scientists Polevoy Yu.I., Tilk IG., T. Manabu, N. Miyaguchi, K. Kumasaka, R. Ishima, Y. Fukuta, KK Tal, A.A. Polyakov, R.C. Taggart, P. Lauria, G. Groat, C. Rees, A. Brick-Turin, A.S. Hakkert, V. Gitelman, W. Okitsu, M.H. Schrader, J.R. Hoffpauer, M.R. Haque, S. Tanvir, P. Rempel, S. Landry, Y. Wang, P. Lautala, D. Nelson, M. Jeon, A. Sidebottom, B. Zaouk, K. Ozdemir and other well-known foreign scholars added.

The analysis shows that safety issues at intersections: analysis of accident statistics at road crossings, use and technical requirements at railway crossings, basic rules for calculating alarm parameters at railway crossings, improvement of protection at railway crossings, the development and implementation of technical solutions to improve safety, modern design principles of emergency warning devices and control sensors at railway crossings have not been sufficiently studied.

CHAPTER I.

ANALYSIS OF THE CONDITION AND PROBLEMS OF RAILWAY CROSSINGS

1.1. Classification of level crossings

At the crossings of the Uzbek railways, railways and other types of vehicles are divided into four categories (Table 1) depending on the intensity of traffic [2]. The traffic lanes shown in Table 1 are of category IV.

The category of crossings also depends on the category of roads and other types of roads (Table 2). The category of roads, in turn, depends on the unit of transport and its importance (Table 3).

Schedule of traffic categories depending on traffic congestion.

Table 1

Type of LC

<table>
<tr><th colspan="3" rowspan="3">Richness of movement</th><th colspan="5">Means of transport</th></tr>
<tr><th colspan="5">car / day</th></tr>
<tr><th>200 until</th><th>201-1000</th><th>1001-3000</th><th>3001-7000</th><th>more than 7000</th></tr>
<tr><td rowspan="4">Trains</td><td rowspan="4">train / day</td><td>do 16</td><td>IV</td><td>IV</td><td>IV</td><td>III</td><td>II</td></tr>
<tr><td>17-100</td><td>IV</td><td>IV</td><td>III</td><td>II</td><td>I</td></tr>
<tr><td>01-200</td><td>IV</td><td>III</td><td>II</td><td>I</td><td>I</td></tr>
<tr><td>more than 200</td><td>III</td><td>II</td><td>II</td><td>I</td><td>I</td></tr>
<tr><td colspan="3">140 km/s movement speed greater than</td><td>I</td><td>I</td><td>I</td><td>I</td><td>I</td></tr>
</table>

All crossings can be classified according to the following main criteria:

- place of use;
- The method of organizing traffic on the crossing;
- crossing equipment;
- crossing service;
- category of crossings;

- location;
- type of alarm for vehicles;
- type of alarm system for railway transport.

Figure 1 shows the classification of crossings. The crossings will be located at the intersection of public railways and public highways. Municipal highways and streets are called public crossings, and areas where railway tracks of individual enterprises and organizations intersect with highways are called non-public crossings.

Dependence of the category of crossings on the category of cars and other types of roads.

Table 2

Category of LC

Category of LC	Category of railroad tracks
I	Category I and II highways. Tram and trolleybus traffic on city streets and roads. Intersection of four or more main roads at stations. Level crossing Streets and roads with regular bus traffic of more than 8 train-buses / hour.
II	Category III highways. Streets and roads with regular bus traffic no less than 8 train-bus / hour traffic. Urban streets and roads without trams, trolleybuses and buses with more than 50,000 train crews / day. The intersection of the three main roads at the station.
III	Except for Category I and II roads, roads with satisfactory visibility of more than 50,000 train-crew / day
IV	Less important highways that do not fall into categories I, II and III.

They are divided into adjustable and non-adjustable level crossings depending on the method of movement organization. There are three types of adjustable level crossings: level crossings equipped with PS devices that warn drivers of the approach of a train to the level crossing; level crossings equipped with service worker duty and PS; It is not equipped with ps devices, and the adjustment of the movement is carried out only by the working shift service level crossings.

The service is organized in the following cases, regardless of the presence or absence of PS:

- I category;

- Category II, with more than 16 trains / day traffic and white flashing lights and station at ASS level crossing traffic lights

- Areas for which there is no automatic control of the failure of PS devices on duty DSP or train duty.

Dependence on the category of roads of both administrative and economic importance.

Table 3

Category of LC

Category	Calculation of traffic richness, avt / day		Administrative and economic significance of the highway
	For cars	Transport unit	
I -a	More than 14,000	More than 7,000	National and international highways
I-b	More than 14,000	More than 7,000	Roads of national, republican and regional significance (except category I-a)
I	6,000 to 14,000 each	3000 to 3000 each	
II	2000 to 6000 each	1000 and 3000 each	Roads of national, republican, regional, local significance (except for categories I-b and II)
III	200 to 2000 each	100 to 1000 each	Roads of republican, regional and local significance (except for categories I-b, II and III)
IV	200 each	100 each	Roads of local importance (except for categories III and IV)

In the absence of PS, level crossing services are provided in the following cases:

- at the intersection of three or more main railway tracks;

if the visibility conditions in category II level crossing are unsatisfactory, if the visibility is more than 16 trains / day, regardless of the visibility conditions;

- if the visibility conditions in Category III level crossing are unsatisfactory, the traffic intensity is more than 16 trains / day or the traffic intensity is more than 200 trains / day, regardless of the visibility conditions.

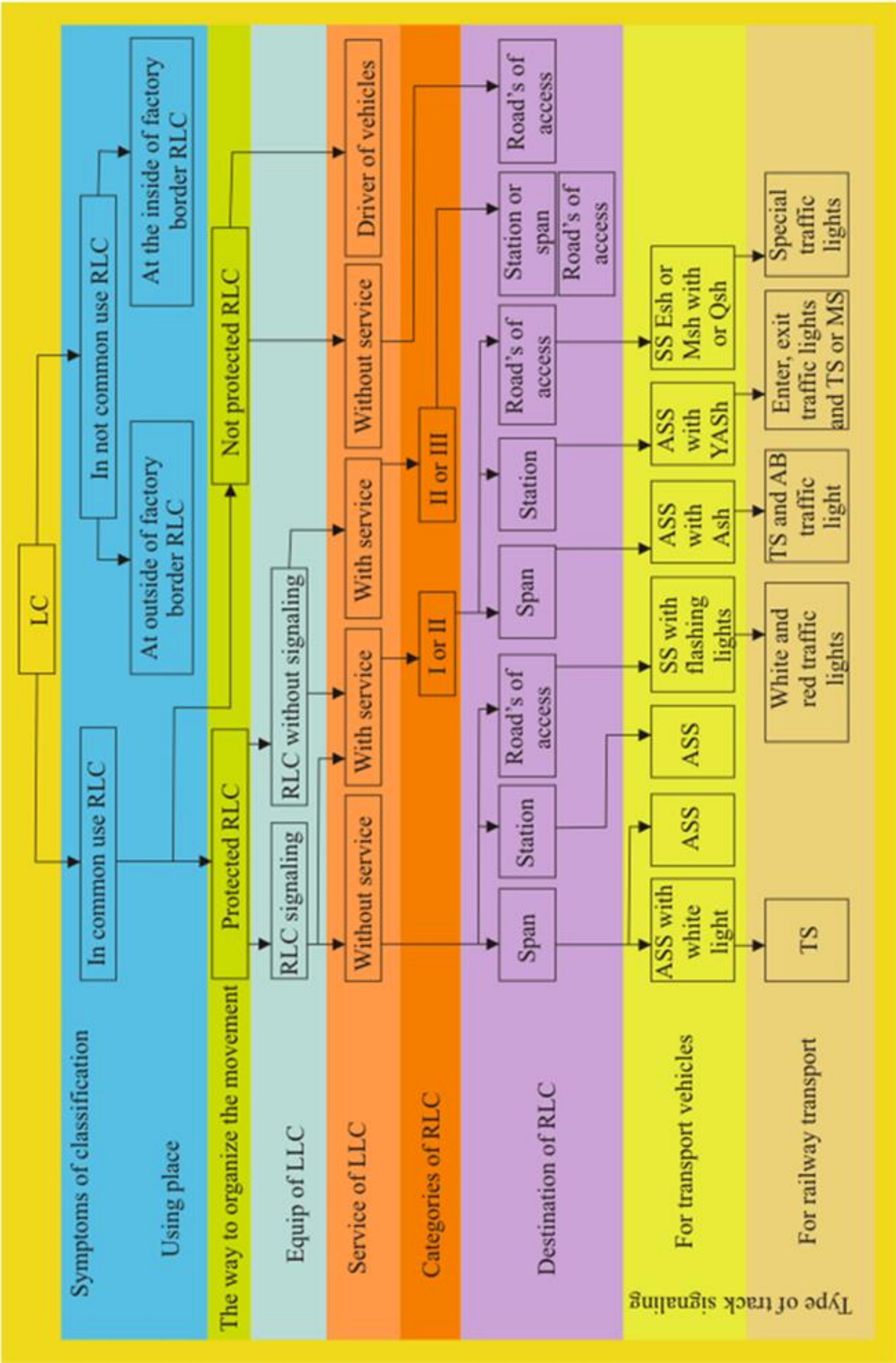


Figure 1. Classification of railway level crossing

Level crossings equipped with PS are not available in the following cases:

- in level crossings of any category of hauls;

- level crossings are located on the receiving and sending tracks of the station;

- on the access road and other roads, as well as on the city border, when the section approaching the level crossing is not equipped with rail chains of normal length.

In these cases, level crossings are equipped as follows:

a) for stop vehicles – with ASS (automation, communication and signaling) light, for railway transport – special stoplights (TS) for trains traveling on the wrong track;

b) for vehicles at stations (except for those located on the receiving-sending tracks) - ASS, for railway transport - by analogy to point (a);

c) on access roads and other roads, as well as on the city border, when the approach to the level crossing is not equipped with normal-length rail chains – with flashing lights, for railway transport - special traffic lights with red and white lights with, the compiler or locomotive brigade or special sensors automatically when the train enters the control zone.

on the access road, in which the head of the railway establishes the order of movement of rolling stock with the participation of the compiler or locomotive crew, level crossings are equipped for vehicles - SS, for railway transport – assigned worker-controlled red and with special traffic lights with white lights.

PS existing level crossings are equipped as follows:

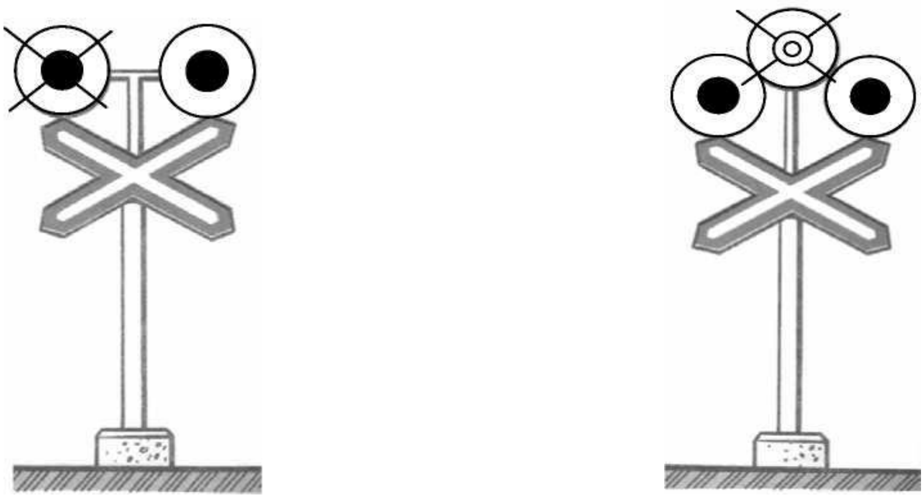
a) for vehicles on hauls – with ASSASh, for railway transport – at a distance of not more than 800 m from the TSva level crossing, the distance of AB (o), which provides the view of the level crossing from the place of their installation Intermediate (crossing) traffic lights close to the level crossing are closed with stoplights;

b) for vehicles at stations – with ASSYaASh, for railway transport – with train stoplights with additional red lights;

c) from access roads where approaching areas cannot be equipped with RZ, for vehicles - with SSESh (MSH), for railway transport – with special traffic lights with red and white lights under the control of the assigned worker.

1.2. Level crossing stoplights and roadblocks PASh-1 and SHA

Serviceable and non-serviceable level crossings are equipped with PS, which generally include: crossing traffic lights; barriers (ASh, AMSh, eSh); PTQ devices; PS control boards.



a) The approach plot is busy **b) The approach area is empty**

Figure 1.2. Level crossing stoplights with duty (a) and without duty (b)

Uzbek railways use four types of level crossing traffic lights: two (type 11-69) and three (type Sh-69) signal heads for one-way sections; two (type 11-73) and three (Sh-73) signal heads for two-lane sections. The ZPT-24 electric bell can be installed on the mast of the traffic light. The level crossing stoplight of non-serviced level crossings shall be equipped with a “Beware of the train” warning sign. Level crossing stoplights shall be installed on the barrier poles or on the right side of a separate roadway at a distance of not less than 6 m from the edge of the rail head, ensuring good visibility for drivers. Figure 2 shows level crossing stoplights for serviced and non-serviced level crossings.

Barriers block the passage of the highway when the entrance is closed for traffic. Currently, in the construction and reconstruction of railways of Uzbekistan, developed by RGOTUPS specialists, operating in automatic, semi-automatic and manual (local control) modes [21, 22], standard types of automatic barriers YaASh-1 and ASh used.

Depending on the method of supply of the electric motor (ED), there are three types of barrier operation: three-phase, single-phase (alternating current) and direct current. The PASH-1 barrier (Figure 3) is a set of optical (level crossing stoplight signals and barrier beams) and audible (bell) alarm devices that allow or prohibit drivers and pedestrians from crossing the level.

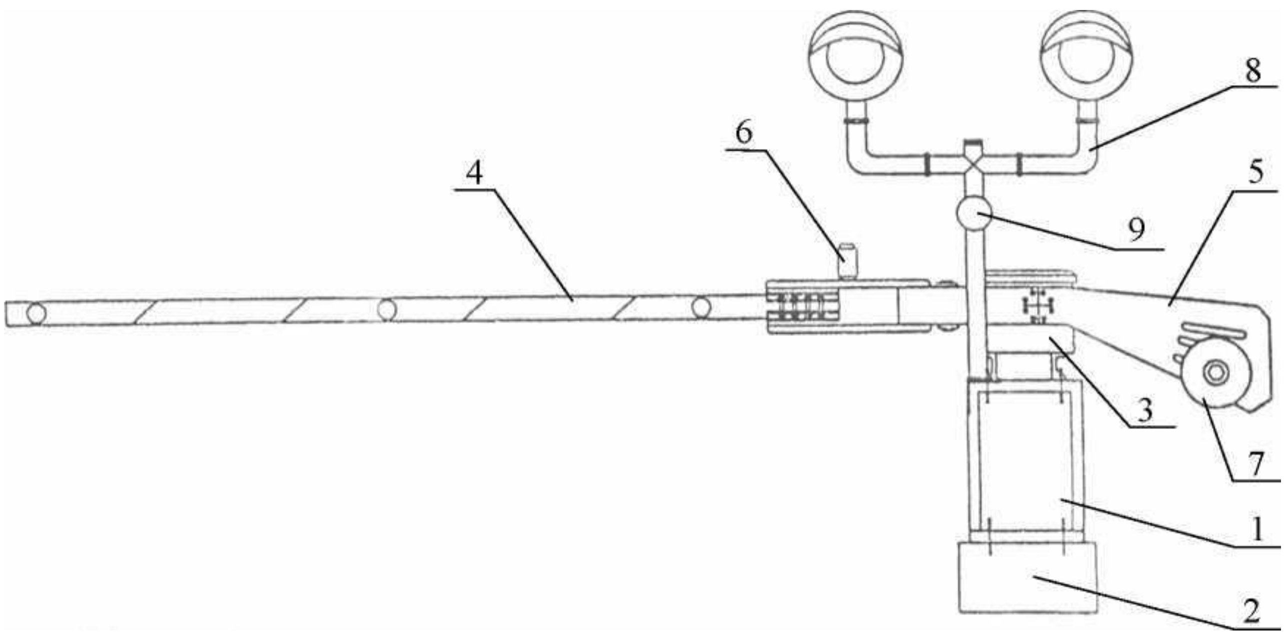


Figure 1.3. PASh-1 barrier

The pedestal 1 is located on the foundation 2 and the electric drive (EP) 3 is installed. at an angle of 90° to the plane in the direction of traffic. Rama 5 has a posangi 7, which in turn is a system that allows the TB to move smoothly to a certain coordinate center of gravity "ZB - rama - posangi". The barrier can be equipped with a traffic light 8 and a bell 9.

The eP performs the conversion of the TB from the closed (transverse) to the open (vertical) position. It blocks the TB in the open position, suppresses the vibration of the TB during movement and stopping, controls the state of the TB (closed, open and intermediate state). Equipped with terminal sockets for eP cable connection, the protection system against manual control of the kurbel handle and TB in case of unauthorized use is related to the safety of the devices and service personnel.

The structure of PASh-1 barrier eP includes: eD operating in single-phase or three-phase network type AIR-56; two-stage reducer; electromagnetic coupling (eM); TB vibration damping damper; Main shaft with two output flanges for fastening the TB frame.

The eP structure of the SHA barrier differs from the eP structure of the PASh-1 barrier in that it uses AIR-63 type eD with a wavy and open cylindrical transmitter, through which the eD is connected on one side to a TB frame fixed to the main shaft.

The TB frame and the shaft are a single moving structure that rotates in a vertical plane around the main shaft. EP brings the TB to an open and closed position.

The TB itself features a box-shaped 100x50mm 0.8 mm thick tunic welded steel structure.

The frame is a structure welded from a tunic 6-8 mm thick. Posangi are discs made of cast iron attached to a frame. The turning device 6 structures of PASh-1 and SHA barriers are different.

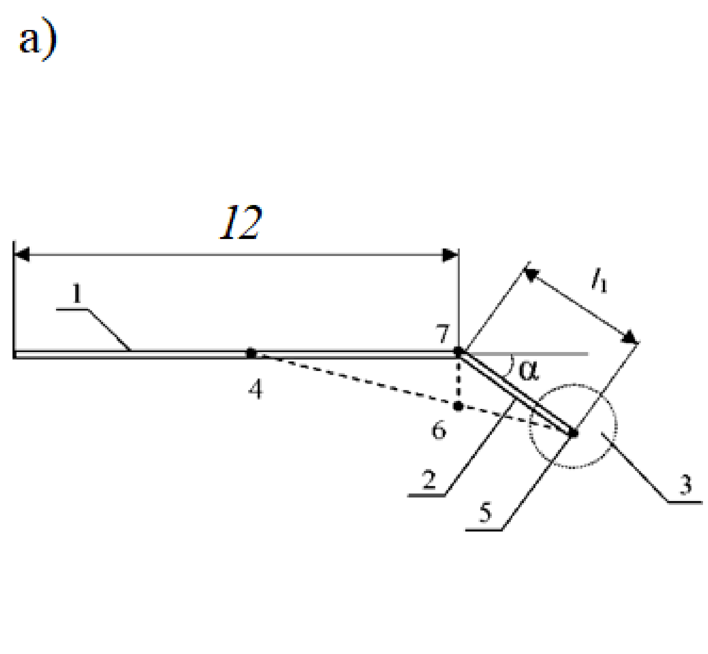


Figure 1.4. The relationship between the center of gravity and the center of gravity of the elements of the system “ZB - frame – posangi”

The barrier beam 1 together with frame 2 and pole 3 have two states: lower (a) – stable and upper (b) – unstable. The structure of the frame and post with TB is such that its center of gravity is taken relative to 6 axes of rotation7 (center of gravity of TB-4, center of gravity of the system "frame-post" 5). This position creates a torque relative to the axis of rotation 7. Therefore, the TB is independent of the transverse (stable) state. The amount of torque is affected by the size of the TB, the weight of the frames and beams, and the angle of intersection of the longitudinal axes of the TB and the frames.

Table 4 shows the length of the TB, the frame and weight of the TB, and the dependence of the “frame-posangi” system (according to m_1 and m_2) on the angle a. It, in turn, maintains the torque M = 170 Nm in the vertical (unstable) position and M = 0 in the transverse (stationary) system of the system "ZB – frame – posangi".

The angle a depends on the magnitudes l1, l2, m1 and m2

Table 4

Parameters of the system "ZB - frame - posangi"				
l_1, m	m_1, n	l_2, m	m_2, n	α, rad.
0,8	43,5	4	160	26,0
0,8	916	6	240	12,0
0,8	1610	8	320	7,0

Thus, lowering the TB is done by its own weight. If an obstruction occurs, the TB can be stopped. Once the barrier is removed, the TB will stop moving.

1.3. The principle of operation of barrier devices in level crossing signaling

The degree of automation and the type of PS also depend on many factors Figure 1. The most important of these are: location, method of organization of traffic, availability of services and category of level crossings.

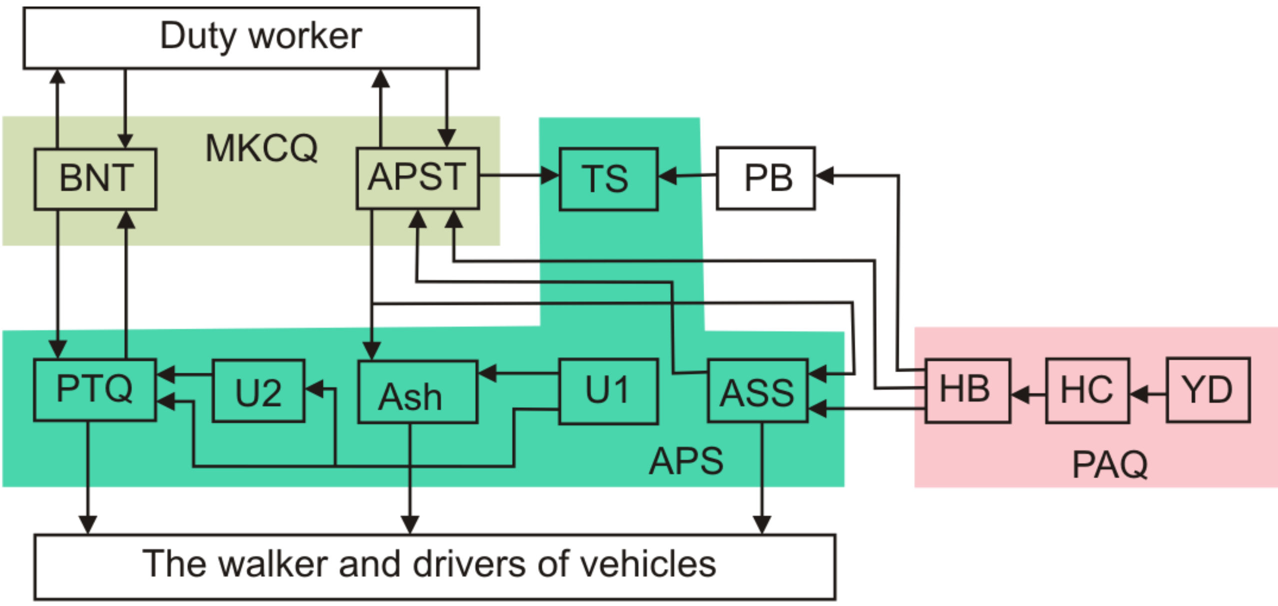


Figure 1.5. Block diagram of APS barrier aurils

The principle of operation of the PS can be fully analyzed, especially in systems with the highest level of automation.

Figure 5 shows a block diagram of automatic level crossing signaling (APS) barrier devices with the highest level of automation of the development phase. The diagram shows train detection devices (PAQ), data input-output devices (ICDs) and APS devices. They include the following elements:

- YD (road sensors indicating that the train is approaching the level crossing);
- HCh (limit of calculation of the area of approach to level crossing);
- XB (notification that the train has entered the approach line);
- U1 (barrier closing retention time element);
- ASh (automatic barrier);
- U2 (retention time for lifting PTQ covers
- elements);
- PTQ (railway level crossing devices);
- PB (level crossing devices from vehicles);
- TS (barrier stoplight, which transmits the command to stop in the cab of the locomotive in the event of an accident in level crossing);
- APST and BNT (control and control panel depending on APS and PTQ)

YD records the arrival of the train, and after HCh determines that it has indeed entered the level crossing approach, the XB channel transmits the control command, i.e., the following sequence for the train to move along the level crossing:

a) ASS connection and barrier closure;

b) check the level crossing gap with the PB device;

c) Lifting the PTQ cover;

g) informing about the approaching train, operation and status of PS devices by means of APST and BNT;

d) Inform the driver of the vehicle about level crossing.

Thus, when the train enters the approach limit, the ASS operates through the XB channel, then the indication in the APS, the PB device and the U1 element are activated, which transmits the ASh command after the capture time t to close the TB, then the time in the U2 element and PTQ. counting, checking that the PTQ devices are operational and that there are no vehicles on the covers. Once this is done, the PTQ gates will be raised.

PB devices check the level of crossing. It should be noted that these devices are not yet used in the railways of Uzbekistan, as there are no standard solutions. The technical solution of PB is given in [6]. A radio sensor has been proposed as a hazard detector in level crossing. It, in turn, ensures that the signal irradiated by the transmitter of the gap contact sensor with the vehicle is shielded by them. When there is a traffic jam at the level crossing (accident at the level crossing), the TS automatically lights up to stop the train immediately. The TS can also be switched on independently by the worker on duty.

Level crossing approach section is a section between a level crossing and a train moving in the direction of the level crossing, the minimum length of which ensures that the level crossing is completely cleared by vehicles until the train enters the level crossing.

Thus, the safe movement along the level crossing and its throughput, in part, depends on the length of the approach section, which is set in two ways:

a) Tables 41247/784 for calculations and instructions for the design of automation, telemechanics and communication devices;

b) automatic PAQ.

The first method is widely used by Uzbek railways [7]. In pergolans, the length of the approach to the level crossing is determined by the following expression:

$$L_{pr} = 0{,}278\text{-}V_{pm}4_{S}, \qquad (1)$$

Here:

0.278 - coefficient of speed transfer from km / h to m / s;

VPM - maximum set speed on a given section (km / h);

K is the notification time (the time for sending a message to the level crossing that the train has entered the approach section).

In turn, the reporting time is determined by the following formula:

$$t_c - t_l + t_2 + t_3,$$

Here:

t1 is the time of entry of the road train by level crossing (the length of the road train is assumed to be 24 m);

t2 – start time of PS and PTQ devices (4 s adopted in MPS); Guaranteed time of t3 – MPS (10 s).

The magnitude of t1 is derived from the following calculation

$$t_1 = (l_i + l_м + l_o)/U_м,$$

Here:

l_P – the intended length of the level crossing (distance from the level crossing stoplight or barrier to a point 2.5 m from the last rail behind the level crossing);

$l_м$ – the intended length of the vehicle (24 m);

l_0 – distance from the vehicle stop to the level crossing stoplight or barrier (assumed to be 5m in MPS);

$U_м$ – The minimum speed of the vehicle through level crossing is 5 km / h (1.4 m / s) at MPS.

Taking into account the norms in the MPS:

$$S = 35 + 0,72/_P > 40 \text{ s}.$$

The length of the approach area is determined as follows when there are different types of barriers:

a) Increases the notification time by 10 s in the case of AOS:

$$L_{pr} - 0,278 i_{pm} 4 s_0,$$

Here:

$$S_O - 45 + 0,72/_P > 50s;$$

b) In the case of ASH and ASH, the reporting time is determined by the expression (1).

In practice, the actual length of the approach section is determined by calculating the location of the LPF track sensors, taking into account the presence of the train (for example, the placement of insulating connections in the blocking block sections is made taking into account the following condition LPF> LPR).

For level crossings located in the neck of the station and on hauls, the notification time is determined by taking into account the time of departure of the train from the entrance traffic light, if the station tracks are part of the approach section. If the SH (calculated) and SF (actual) notification times do not match, the PS will light up after the command to turn on the exit stoplight is sent, which will only open after a delay time equal to tB - tCT - SF.

The disadvantage of modern barrier devices in railway level crossings is that their reporting time is the maximum speed of the fastest trains for level crossings, while for stations it is a single electric locomotive (0.8 m / s) and a diesel locomotive (0.6 m). / s) is determined taking into account the acceleration.

Real trains run slower, so level crossings are longer than closed time for vehicles to move. This situation reduces the throughput of level crossings, and at the same time causes traffic jams for a long time.

Adjusting the notification time, the actual speed, and the acceleration of the train movement would have significantly increased the bandwidth of the level crossings.

Taking into account the above requirements, a set of level crossing devices (PAKU) has been developed at GTSS to implement the second method of determining the length of the section approaching level crossing [8]. This complex allows to determine the actual distance to the train (in its approach and departure), reduce the time of the closed position of the track for vehicles by the speed and acceleration of the train. Experiments with PAKU have shown that the closed state of level crossing is reduced by an average of 20% if one category of trains moves from level crossing, and by 50% or more if different categories of trains run.

1.4. Improving the safety and functional efficiency of railway crossings

Crossing the railroad is a danger zone. Unauthorized movement of moving vehicles at railway crossings can have serious consequences. This is mainly due to the fact that passengers are seriously injured in accidents, vehicles are damaged and cargo is lost. The main reasons for the raids were that drivers of vehicles at guarded crossings bypassed the closed level crossing, and vehicles at unguarded intersections moved in a hurry before the train approached the traffic center [4, 5]. These studies were performed on the basis of a scientific framework framework (Figure 1.1). The investigation of the problem was carried out using the equipment and auxiliary equipment and documents related to the object.

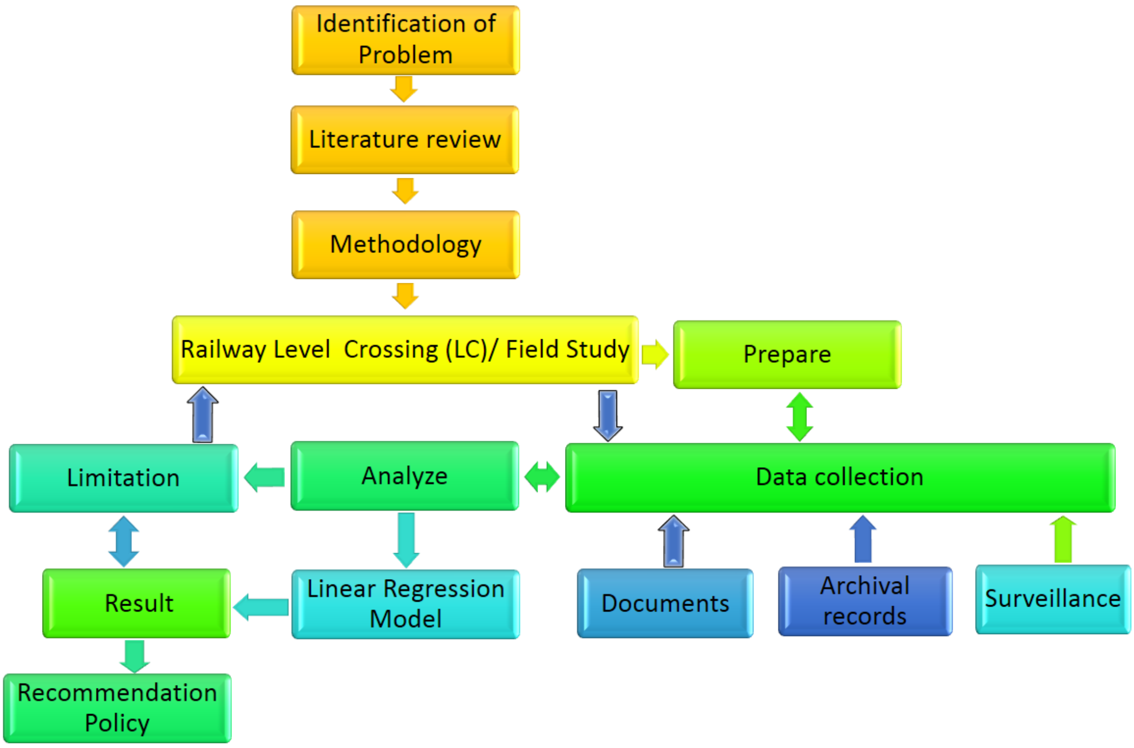


Figure 1.1. Scientific work framework

In this regard, many authors have made many scientific proposals and analyzes in their scientific articles on improving the work of railway crossings. Research by

Manabu and co-authors focuses on safety and reduces warning time when crossing a railroad. Long warnings can be a nuisance for those trying to cross a railroad crossing. In this study, they studied two transition levels to reduce the railway crossing warning time: normal and downtime. A microelectronic level switching device has been developed that has a built – in constant warning time control logic for the normal state of level crossing. In the event of a fault, a mechanism has been developed to prevent a long warning time when a railway crossing detects a fault. In particular, it is connected to railway crossings in the network and is managed using data from other level crossings instead of unsuccessful crossings [6]. The first publications on the calculation of vehicle delays at road crossings in calculating vehicle delays at railway crossings appeared in the late 1940s in the research of B.D. Steinj. Over time, the problem of delays became more acute, and there was growing interest in developing an intersection theory. Several formulas have been proposed, but none of them has been widely used in the form of applications.

According to the recommendations of the above authors, the approximate amount of delay can be found as follows. Tall was able to develop his scientific research. If the vehicles pass through the intersection in the order of approach to the intersection, then the total delay time for one of the two intersecting routes will be as follows:

$$T_1 = \frac{N_1 N_2 t_2^2}{2*1440} \quad \text{minutes per day} \qquad (1.1)$$

where N1 and N2 are the dimensions of the traffic on the intersecting routes;

t2 - time of intersection of one unit of "opposite path" (in minutes);

1440 is the number of minutes in a day.

A similar delay formula for another route is as follows:

$$T_2 = \frac{N_1 N_2 t_1^2}{2*1440} \qquad (1.2)$$

If one of the routes (for example, the first) has advantages, ie the flow in it is missed without delay, the amount of delays for the other route is determined by the formula [7]:

$$T_2 = \frac{N_1 N_2 (t_1 + t_2)^2}{2 * 1440} \quad (1.3)$$

As mentioned above, the work of road and other types of urban transport specialists, as well as urban planners together with scientists and engineers of railway transport to develop the theory of intersections and determine the delay of rolling stock in transport networks took. Polyakov was invited to determine the costs incurred as a result of traffic delays at intersections.

$$\prod_0 = 365 \left[\sum N * \frac{n}{18} * \frac{\tau}{60} * \frac{\tau}{2*60} * R + S * \sum \left(\frac{1}{\vartheta_0} + \frac{1}{\vartheta} \right) N * R (P_1 + P_2) \frac{n}{18} * \frac{\tau^2}{7200} * R_1 \right] \quad (1.4)$$

where N is the average number of transport units of each type passing through the crossing in one day in both directions;

$\frac{n}{18}$ average number of traffic closures per hour (from 6 to 24 hours without n trains);

t – the average duration of the closed position of the intersection (min.);

R – idle time of transport unit, sum / hour;

S – the length of the approach section to the crossing, including the moving zone and the acceleration distance to normal speed, km;

Uo – average speed of ground transport in the moving zone, km / h;

P I + P2 – the average number of passengers and pedestrians crossing and crossing in both directions during the day;

Rr – the average cost of an hourly wage lost while waiting, sum.

The above formula allows to determine the delay in travel in the moving zone and the associated costs, taking into account not only the rolling stock, but also the economic damage caused by delays for passengers and pedestrians, as well as the reduction of surface transport speeds [8]. Taggard studied some formulas to calculate the delay of each vehicle at the intersection. These equations are based on the average annual turnover, vehicle movement, and closing time, which is calculated from the average length of the train and the average speed of the train during the transition [9]. Hackert and Gitelman have developed a simplified tool for assessing transitions in

Israel. From the area data collected in the 31 most problematic locations, they calculated the cost of safety problems and travel delays and used them to compare the cross-sectional characteristics of the surfaces [10]. Okitsu and others recorded 24-hour video at 33 crossings in the San Gabriel Valley, Los Angeles County. From the records, they identified several parameters, such as the phased flow signal and the green ratio of the downstream cycle, and applied them to the Webster intersection delay model.

Thus, delays are detected in each individual event during the day due to obstacles at railway crossings.

$$D = [AR * Q * (B + LT)]/2 \quad (1.5)$$

Here:

D = total delay of car-hours;

B = duration of the blocking event in a few hours

AR = vehicle speed per hour;

LT = Time lost in a few hours

Q = queue duration in hours [11].

Schroder and Hoffpauer developed a methodology for prioritizing potential highways and railroad junctions in Central Arkansas. In this method, the delay time at a railway crossing is one of the seven factors included in their analysis and is estimated using formulas developed by Taggart et al. [12]. Haque et al analyzed three different scenarios of econometric analysis. The first scenario is not to relocate the intersection and to improve the existing railway crossings. The second was analyzed without crossing the intersection, but with crossings separated from the intersections at 9 main locations. Finally, it reviews the intersection strategy. The equation for determining railway delays is derived from Webster's equation, one of the basic equations of traffic flow theory. Details of how this equation was changed are provided in the Memorandum of Access Duwamish Grade Delay Analysis (Heffron

Transportation, 1997). The resulting equation determines the total delay of car-hours for one road approach per hour. The delay for each hour in each direction is found from the equation:

$$D = \frac{\lambda n \mu r^2}{2(\mu - \lambda)} \tag{1.6}$$

These values are then combined for the entire day and the overall transition level. Here, D = total delay per vehicle hour, λ = Arrival rate of vehicles (vehicles per hour), μ = speed of queue distribution (vehicles per hour), r = average obstacle time at the intersection (hours), n = number of traffic jams per hour (similar in size) [13]. Peter et al. Analyzed on the basis of a geographic information system: the analysis showed service zones, in which the barrier was lowered and not lowered when crossing the fire safety intersection, as well as the fire truck going to the fire situation and considered in the case of crossing the intersection in the normal case. Both analyzes were quantitative and both showed results. Avoid detours that are presumed to be blocked, avoid chasing a route that is considered blocked, and then have to turn around and cross the rail at the intersection the choice of waiting for an obstacle at the crossing shows that the tracking system shows that this detour is more efficient than the detour. [14]. Rempel et al. Reported the exact location, time, and duration of a specific incident or possible incident to various users, including emergency dispatchers and drivers, news media, vehicle management systems, and the general public. created and patented a system that automatically delivers an intersection event or a possible event. The system uses several technologies to detect activity on the railway [15]. It transmits a database of data, performs various analyzes on the data, and notifies the status of the transition point (blocked, potentially blocked, approaching, blocked, or clear) and more to different users, developed an information-assisted system for informed decision-making [15].

1.5. Results of the analysis of railway crossing facilities and equipment

Railroad crossings (crossings) are level crossings of railway tracks equipped with the necessary level of safety devices. There are 1,380 railway crossings in the Republic of Uzbekistan. Uzbekistan Railways has 575 crossings, of which 146 are guarded and 429 are unguarded. There are only 805 railway crossings at the entrances of the republic's ministries and departments, of which 28 are guarded and 777 are unguarded.

The U.S. Department of Transportation’s Federal Railway Administration, a review of articles and research that has been conducted, is focused on examining people’s behavior when crossing a railroad crossing. The study focused on factors influencing driver behavior, factors affecting driving ability and driving style, respect, age of driving ability, experience, internal or external distractions, and factors affecting driver impairment [17]. Since crossing negotiations are only one aspect of the driving task, research on the driver’s general behavior has included cases related to the crossing problem. The document contains literature on the effectiveness of countermeasures against driver compliance [17]. Describes the behavior of drivers at simulated railroad crossings modeled after realized railroad crossings included in the Naturalistic Driving Study data set from Steven et all. The results show that drivers may not be able to properly respond to obstacles and active warnings when they are off [18]. Participants performed the safest actions in response to STOP signs. The majority of participants reported increased vigilance and corresponding behaviors after repeated exposures to railway crossings, supported by the results of a linear regression analysis [18]. Adam Sidebottom's "Active Control Crossing" is a pedestrian crossing where warning devices warn road users and pedestrians about an intersection, such as flashing lights or barriers to rail traffic. If it is determined that the railway vehicle has reached a predetermined warning distance from the railway crossing, the active control system will activate the crossing protection device. This is to ensure adequate warning time corresponding to the maximum speed of the road. The activation point can be an exact position determined by design calculations or, if set, can be dynamically determined by the intersection prediction system [19].

Railroad crossings are divided into guarded and unprotected. Guards include railway crossings equipped with crossing signaling devices for drivers of vehicles or on duty. Unprotected railway crossings include intersections that are not equipped with signaling devices and are not serviced by the duty service. The driver's ability to cross safely is determined by the driver of the vehicle. Equipping the existing crossings will be carried out by the divisions of the joint-stock company (JSC) as soon as possible [20].

Automatic signaling system – light signals crossing the railway, acoustic signals, electric railway rail chains (approaching section) and the approaching part of the train, providing the railway crossing to A system consisting of an audible alarm, control equipment that automatically sends a notification and provides automated activation [21]. The audible alarm goes off automatically when the back of the train leaves the intersection. The railway may be provided with flashing lights at the intersection. Intersection signaling is used in conjunction with automatic barriers at the railway crossing on duty [21].

Railroad crossing signaling is a general equipment used at railway crossings with electric barriers, automatic stoplights, automatic stoplights with automatic or semi-automatic barriers. These include traffic lights (for drivers of vehicles) and audible (for pedestrians), electrical rail chain equipment and signal control equipment, and at intersections with duty, as well as barrier equipment and controls.

At the same level of railway and highway intersections there are railway crossings. To ensure the safety of trains and vehicles, railway crossings are equipped with security devices to block the movement of vehicles in a timely manner when approaching a railway crossing [22, 32, 43].

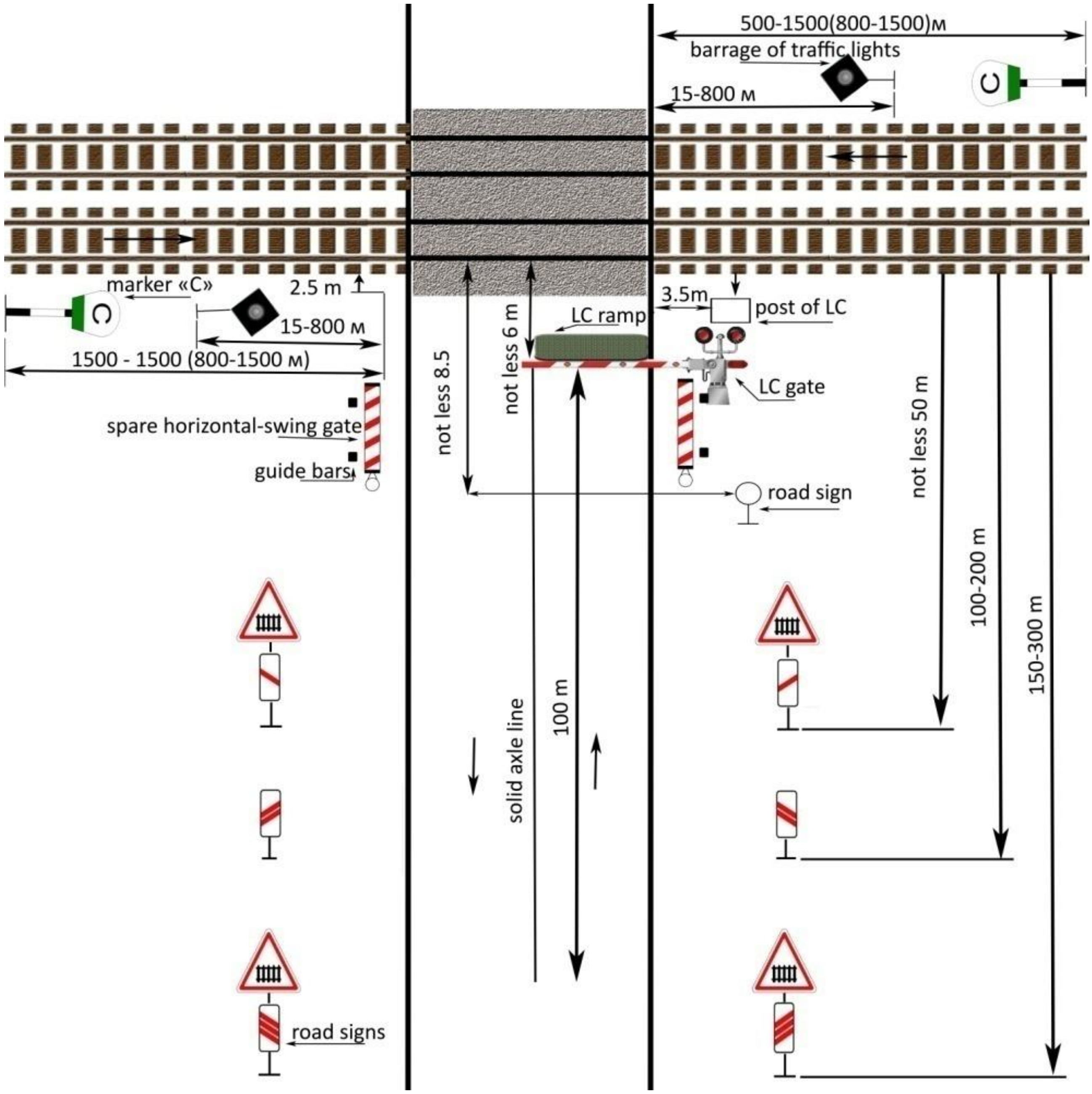


Figure 1.2. Location of railway crossings

Depending on the intensity of traffic, the following types of shut-off devices are used at railway crossings: automatic traffic signaling; automatic traffic alarm with automatic barrier and railway crossing barrier (UZP); consists of an automatic alarm with non-automatic barriers. The block diagram of the current guarded intersection is shown in Figure 1.3 below.

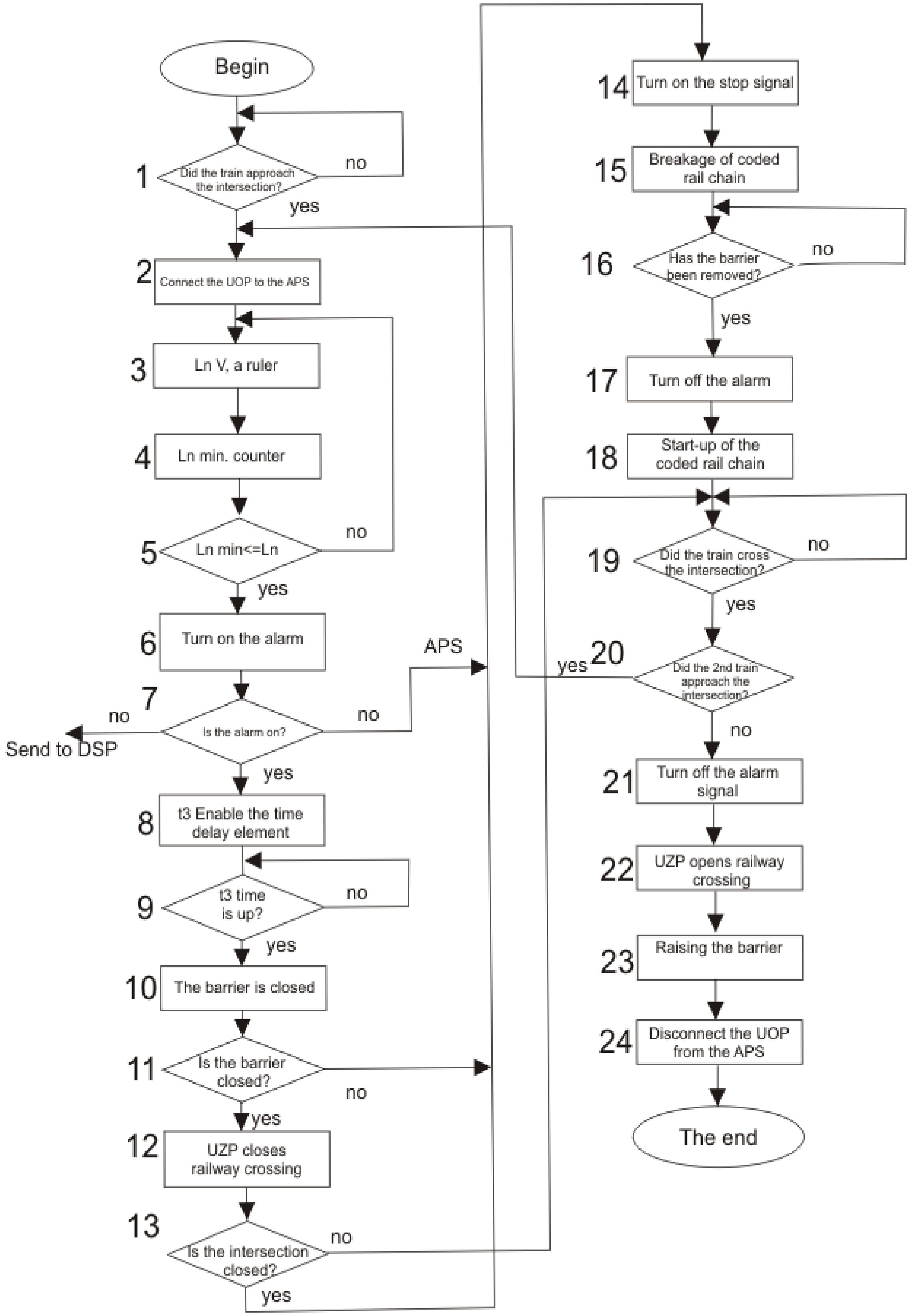


Figure 1.3. Operational block diagram of the guarded railway crossing

1.6. Practical experience of the world railway, analysis of the problems of regional and urban railway crossings

The European Union is an organization with a population of 502 million in 2012, consisting of 27 countries. According to the European Railways Agency (YETA), there are about 123,000 (in 2010) railway crossings on national railways, with an average of 10 lines / km [23].

Only 29% of their users are equipped with active protection crossings (manual or automatic barriers and / or visual and audible alerts). Other level crossings are called passive level crossings (no protection, only road signs: for example, STOP).

There were 619 accidents in the European Union in 2010 (831 in 2009) and 359 deaths (without suicide) in 2010 (405 in 2009) [23].

According to YETA, 45% of car accidents in the European Union in 2010 were caused by cars, 20% by heavy vehicles, 22% by pedestrians (elderly people, dog leaders, other people who spend their free time), vulnerable people).

Accidents at railway crossings in the European Union account for 30% of all railway accidents, but only 1.2% of road fatalities (0.2% in the UK, the lowest in Europe). In 2009, 35,500 people were killed on the roads, of which only 405 were at the railway crossing, so this is considered a minor problem for the road but a major problem for the railway [23].

In 2012, there were 7.3 billion people living on earth. It is estimated that there are one million intersections in the world and more than 6,000 people die each year (the differences vary greatly from country to country). According to the World Health Organization (WHO), more than a million people worldwide are involved in road accidents each year, 90% of which occur in low- and middle-income countries.

In 2001-2007, at the railway crossings of the Republic of Uzbekistan, there were 224 collisions of railway traffic, unprotected crossings in terms of the number of collisions: in general, 168 crossings out of 224 traffic situations were not allowed at railway crossings, which is 75% of the total number of crossings, and this occurred when most of the unprotected intersections had almost automatic crossing signaling devices [24].

Between 2002 and 2004, the death toll from raids rose sharply to 10 a year. In 2005, the number of deaths decreased by 2 times compared to previous years and increased by 40% in 2006 compared to 2005, and the number of deaths due to collisions in 2007 increased by 28% compared to 2006 [24].

The analysis of collisions at railway crossings revealed that the lowest level of collisions occurred with light vehicles: for example, 17 out of 24 collisions in 2001 (71%) cars and motorcycles, 27 out of 37 collisions in 2006 (73%) - passenger cars, 27 out of 36 raids in the 12 months of 2007 (75%) - to cars. This testifies to the frequent violations of traffic rules and railway crossing rules by drivers of passenger cars, as well as their irresponsibility when crossing railway crossings [24, 63].

1.7. Modern trends in the improvement of control sensors for the approach of trains to railway crossings

The main purpose of this section is to study automated crossing systems to prevent accidents between trains and road users. From the point of view of crossing the railway, the protection requirements are very simple. All road users must be stopped before the train can pass. Particular attention is paid to the wheel sensor, which is used to accurately track the train, which controls the direction and speed of the train. Two-wheel sensors are installed before and after the intersection. On the other hand, the proposed system consists of other warning devices such as automatic barriers, lights and alarm devices.

Let's take a look at some scientific articles that are close to the above assumptions. Bochetti et al used a security management system that combines non-heterogeneous access detection, access control, intelligent video surveillance, and voice detection using video analytics and artificial intelligence. For most alarm signals (including motion detection, unattended load, crossing the yellow line), a probability of detection of at least 80% and a false alarm level were observed for at least 10 adverse signals per day [25]. Salmane et al. Dempster-Shafer identified dangerous situations at the intersection with video analysis based on the covert Markov model [26]. Govoni et al. Used modern, defined object scanning algorithms to monitor railway crossings with ultra-wideband technology [27]. François Govoni and others propose a system aimed at improving safety and minimizing risk at the intersection between road and rail by tracking the location of road vehicles through a mobile device application. A neural network prediction model is also used to predict the arrival time of trains [28]. Allotta et al. Conducted research on train detection algorithms. Rail and bullet meters are used to detect trains because they are the two main detectors used to ensure safety at railway crossings. By knowing the location of the train, they can easily predict the speed of the train, the minimum closing time, as well as the number of bullets. The above parameters were processed using interconnection operations to obtain the actual speed, minimum closing time, as well as the number of bullets. They implemented the model in the Matlab and Comsol Multifhysics environments. The algorithm was performed through simulation to verify the execution of operations [29]. Radalj et al suggested that drivers test their speed before crossing an intersection. The test involves reducing the speed from 110 km / h to 80 km / h at a distance of 600 km. In the analysis of the velocity data, the velocity differences between the marked points were relatively average [30]. Zhang and others proposed a model for detecting a high-speed train by measuring the magnetic field using giant magnetoresistive sensors. They analyzed, modeled and simulated the magnetic field distribution in a high-speed rail system. The results showed the presence of a train, distance, speed and number of rolling stock [31].

Conclusions

1. The causes of delays of vehicles at railway crossings and advanced scientific work on their elimination are analyzed and formulas developed and applied by international authors are analyzed.

2. The purpose of the dissertation is to study the processes of operation of safety devices at railway crossings of the world's leading countries and the structure of sensor elements, as well as the conditions and principles and algorithms of railway crossings in our country.

3. The statistics and results of accidents at railway crossings in regional and densely populated cities of the world were analyzed.

4. Accidents on the Uzbek railways have been studied over the years and the analysis of the main cases is given in percent.

CHAPTER II.
DEVELOPING SCIENTIFIC AND METHODICAL RECOMMENDATIONS TO REDUCE DEFICIENCIES AND EMERGENCIES OF MOTOR VEHICLES AT RAILWAYS

2.1. Adapt the theoretical formulas commonly used to identify and analyze the causes of vehicle delays at controlled railway crossings

The rapid growth of passenger cars owned by Uzbek citizens, on the one hand, will lead to an increase in the number of accidents, on the other hand, will lead to an increase in traffic congestion. At the same time, over the past 5-8 years, the delay of vehicles at railway crossings (jeleznodorojniy level crossing), especially in densely populated suburbs and urban areas, at the intersection of highways and railways has increased sharply [35].

Due to the high rate of motorization of the population of Uzbekistan and the growth of motorists, the problem of road capacity has intensified. When there is an intersection of highways with single-level railway lines, the throughput level decreases by 1.5-2 [31], which leads to a long delay of traffic at railway intersections.

On the other hand, the long-term closure of railway crossings is a significant waste of time for passengers. At the same time, a train running twice a day in a row worsens the situation.

2.2. Assembled parametric model and research algorithm for determining the delays of vehicles at controlled railway crossings

The city is spending more and more time on the flow of traffic. Even on five-kilometer-long routes, passengers stop an average of four or six times. Second, if the traffic is at its peak. Third, if your road has more turns ahead and extra stops at a railroad crossing.

One railway crossing in Tashkent was chosen for the experiment. The study focused on the frequency of daily trains, the closing time of the railway crossing barrier and the number of crossings per day, and the number of vehicles parked on both sides of the crossing at the time of the railway barrier closure. This information is used to calculate different solutions. First of all, determine the delay time of all vehicles when the railway crossing is closed. What percentage of car delays during rush hour is affected by a train crossing? How does the situation affect the population? In the end, it saves time and anticipates delays as the vehicle crosses the road.

In the research approach, access to data is done by intersection, by time, peak periods of peak times, weekends, and weekdays or weekends. In Tashkent, almost all institutions, organizations, educational institutions, etc., the service sector begins at 8 am, and return home takes place at about 6 pm. For this reason, the peak times were chosen to be 7:00 a.m. to 9:00 a.m. for the AM peak and 5:00 p.m. to 7:00 p.m. for the RM peak. There are four working days on Saturdays and Sundays.

Table 5

Calculation of the delay of the vehicle on business days at the railway crossing

Time	Delay (minutes)	Train frequency (number of passes)	Car flow (1 hour car)	Rush time (6-8 p.m., and 17-19)	Shlagbaum closure duration (minutes)
1,2	9	1	234	0	10
2,3	9	1	216	0	11
3,4	12	1	362	0	14
4,5	16	2	651	0	25
5,6	11	1	787	0	13
6,7	10	1	793	0	12
7,8	8	1	827	1	12
8,9	9	1	813	1	13
9,10	9	1	721	0	10

Continuation of the table 5

10,11	9	1	654	0	10
11,12	14	2	602	0	25
12,13	13	2	642	0	25
13,14	10	1	608	0	12
14,15	14	1	614	0	16
15,16	15	2	683	0	26
16,17	16	2	729	0	26
17,18	11	1	846	1	13
18,19	9	1	876	1	11
19,20	18	2	763	0	20
20,21	14	1	724	0	15
21,22	12	1	761	0	14
22,23	0	0	714	0	0
23,24	18	3	768	0	26
24,1	10	1	658	0	12

Based on the research strategy, the data collection period lasts for several days. For information, you can count the time it takes to get on the trains, the number of cars on both sides, and the time to close the barrier. To get information about the delay, the total number of cars waiting is divided by the number of allocated cars.

Table 6

Calculate the weekend delay at the intersection

Time	Delay (minutes)	Train frequency (number of passes)	Car flow (1 hour car)	Rush time (6-8 p.m., and 17-19)	Shlagbaum closure duration (minutes)
1,2	9	1	320	0	10
2,3	9	1	348	0	11
3,4	12	1	365	0	14
4,5	11	1	377	0	14

Continuation of the table 6

5,6	11	1	402	0	13
6,7	9	1	652	1	11
7,8	11	1	764	1	12
8,9	11	1	786	0	13
9,10	9	1	721	0	10
10,11	9	1	654	0	10
11,12	14	2	602	0	25
12,13	11	1	642	0	14
13,14	10	1	608	0	12
14,15	13	1	614	0	15
15,16	15	2	683	0	26
16,17	16	2	729	0	26
17,18	11	1	846	1	13
18,19	9	1	876	1	11
19,20	18	2	763	0	20
20,21	14	1	724	0	15
21,22	12	1	761	0	14
22,23	0	0	714	0	0
23,24	18	3	682	0	26
24,1	10	1	658	0	12

Where ID is the given time interval;

Delay – the average waiting time of vehicles at the intersection (minutes);

Train Frequency – the frequency at which trains cross an intersection;

Traffic flow – the number of crossings of vehicles in a given period of time;

Rush time – 6-8 in the morning and 17-19 in the afternoon;

The duration of the barrier closure is the time (minutes) when the barrier is lowered.

Table 7

Calculation of traffic delays at intersections during rush hour

Time	Delay (minutes)	Train frequency (number of passes)	Car flow (1 hour car)	Rush time (6-8 p.m., and 17-19)	Shlagbaum closure duration (minutes)
7,8	8	1	827	1	12
8,9	9	1	813	1	13
17,18	11	1	846	1	13
18,19	9	1	876	1	11
7,8	11	1	763	1	12
8,9	11	1	724	1	13
17,18	11	1	782	1	13
18,19	9	1	790	1	11
7,8	12	1	925	1	12
8,9	10	1	872	1	12
17,18	18	2	854	1	21
18,19	10	1	862	1	13
7,8	11	1	830	1	12
8,9	11	1	810	1	13
17,18	11	1	850	1	13
18,19	9	1	880	1	11
7,8	12	1	846	1	12
8,9	10	1	768	1	12
17,18	10	1	812	1	13
18,19	18	2	806	1	26
6,7	9	1	652	1	11
7,8	11	1	764	1	12
17,18	11	1	846	1	13
18,19	9	1	876	1	11
6,7	10	1	692	1	12
7,8	11	1	763	1	12
17,18	11	1	782	1	13
18,19	9	1	790	1	15

Table 8

Calculation of overtime delays at intersections

Time	Delay (minutes)	Train frequency (number of passes)	Car flow (1 hour car)	Rush time (6-8 p.m., and 17-19)	Shlagbaum closure duration (minutes)
1,2	9	1	234	0	10
2,3	9	1	216	0	11
3,4	12	1	362	0	14
4,5	16	2	651	0	25
5,6	11	1	787	0	13
6,7	10	1	793	0	12
9,10	9	1	721	0	10
10,11	9	1	654	0	10
11,12	14	2	602	0	25
12,13	13	2	642	0	25
13,14	10	1	608	0	12
14,15	14	1	614	0	16
15,16	15	2	683	0	26
16,17	16	2	729	0	26
19,20	18	2	763	0	20
20,21	14	1	724	0	15
21,22	12	1	761	0	14
22,23	0	0	714	0	0
23,24	18	3	768	0	26
24,1	10	1	658	0	12

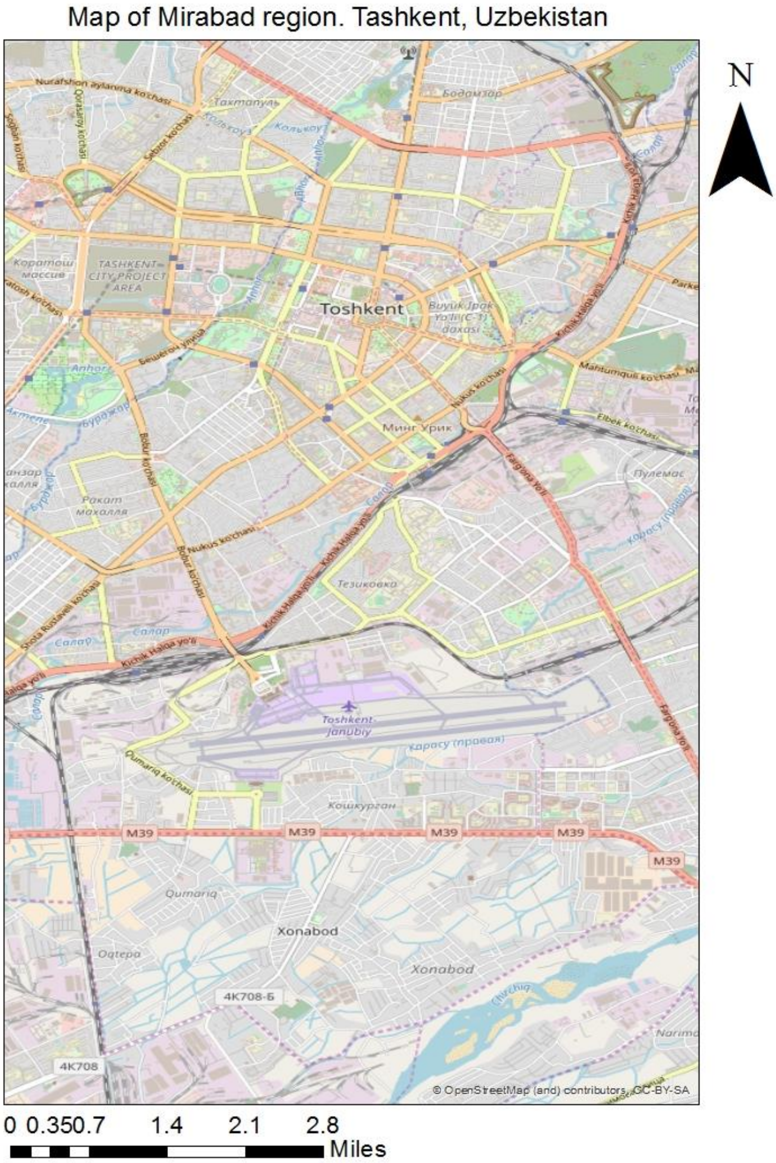


Figure 2.1. Source Yandex map. Location of the railway in the study area

The assessment method is based on Linear Regression. The analysis was conducted in the direction of travel of the road segments that directly affect the intersection. Data are taken at the intersection by rail segment and route, and an interval of 12–15 minutes is considered to be the most mobile time interval in which data sets can be combined. The amount of traffic affected during the busiest period (e.g., 15 minutes) was assumed to be proportional to the length of time the barrier was active. For example, if the barrier is active for 15 minutes every hour, then, on average, 25% of the traffic will be delayed. If the barrier is active two or more times per hour, 50-75% of the traffic will be delayed.

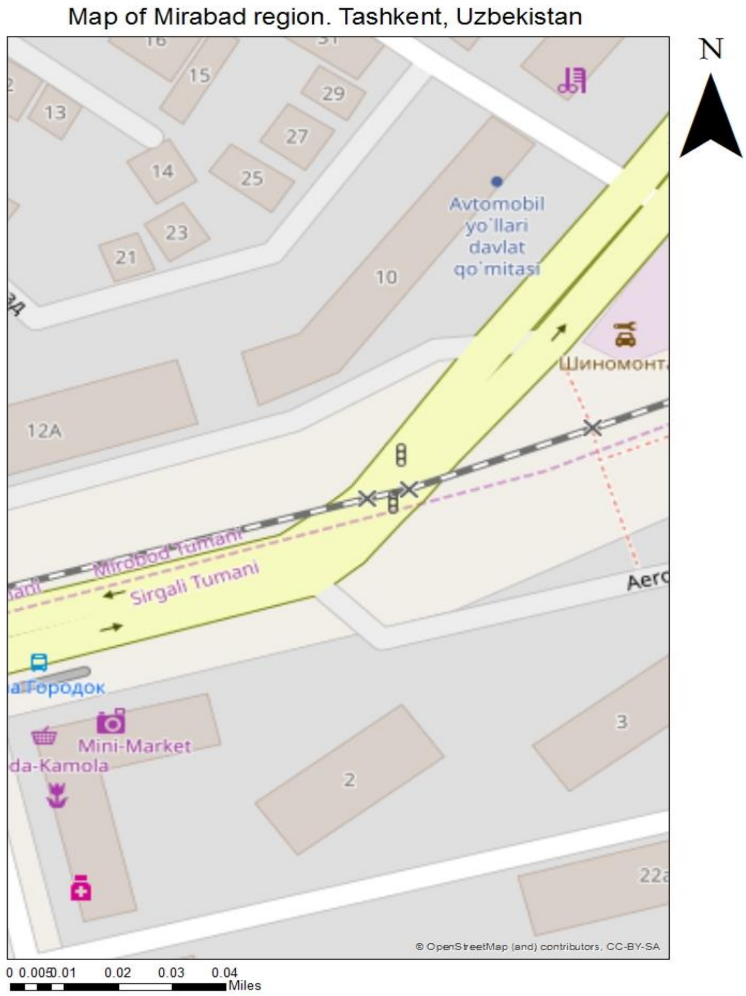


Figure 2.2. Source Yandex map. Railroad Crossing

2.3. Organizational and technical measures to reduce traffic delays and improve traffic safety

Based on the data, the average daily traffic for the considered intersections is 15-16 thousand per day. In total, the barrier is active for a total of 5.5 hours on a given working day. The barrier is on average 50% active during the busy day. The peak periods are between 7-9 and 17-19. When the rail barrier is active, it works with 95% confidence for at least 8 minutes.

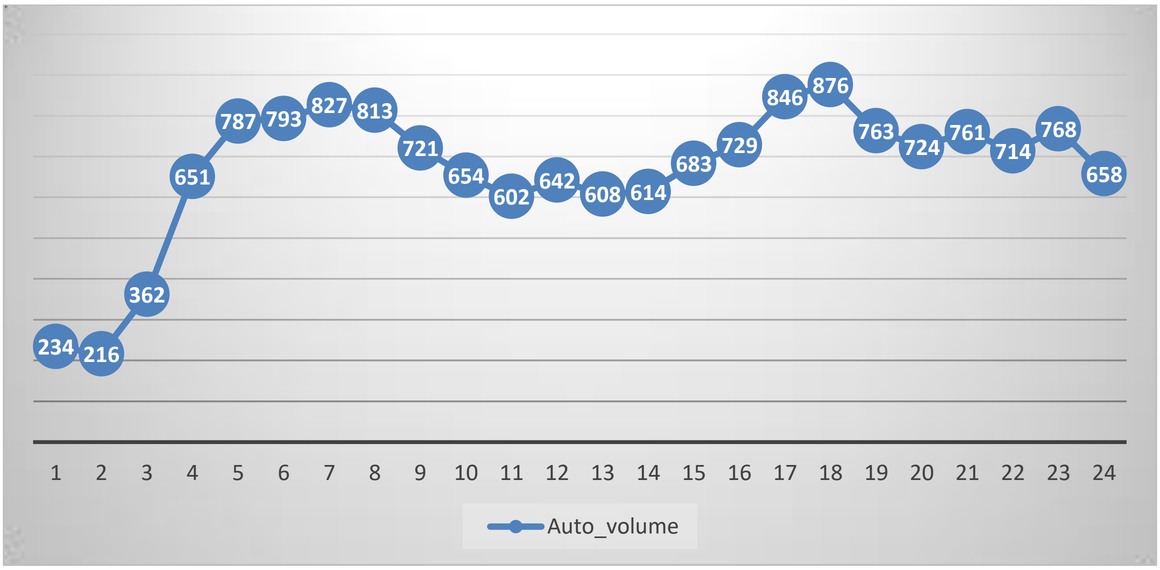


Figure 2.3. Daily schedule of vehicles

The volume of vehicles during rush hour is higher than at other times. At this point, it is difficult to cross the railway. If the train arrives at a busy time, it will be difficult for the vehicles to get out of the traffic jam. There is more traffic during the peak hours than the schedule.

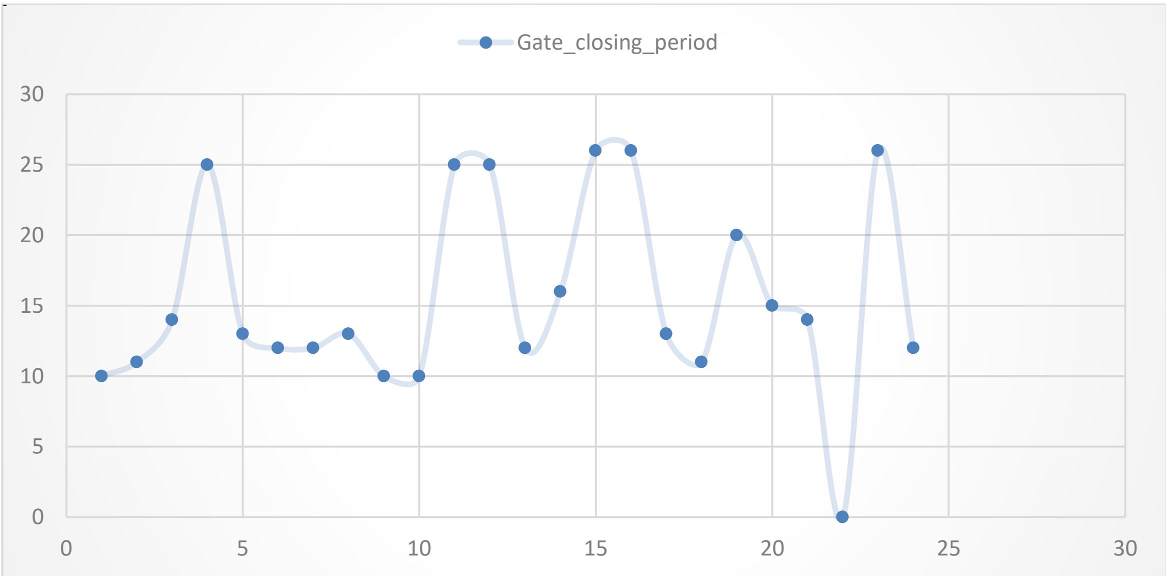


Figure 2.4. Daily barrier closure schedule

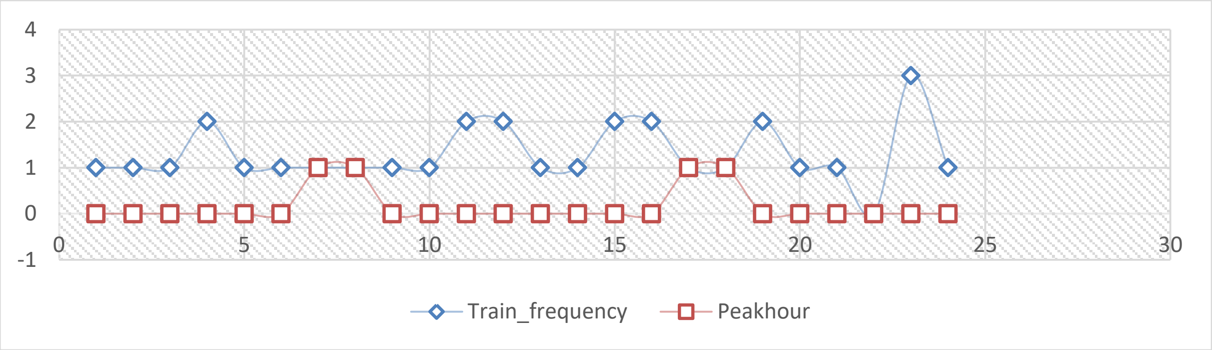


Figure 2.5. Daily train frequency and busy schedule

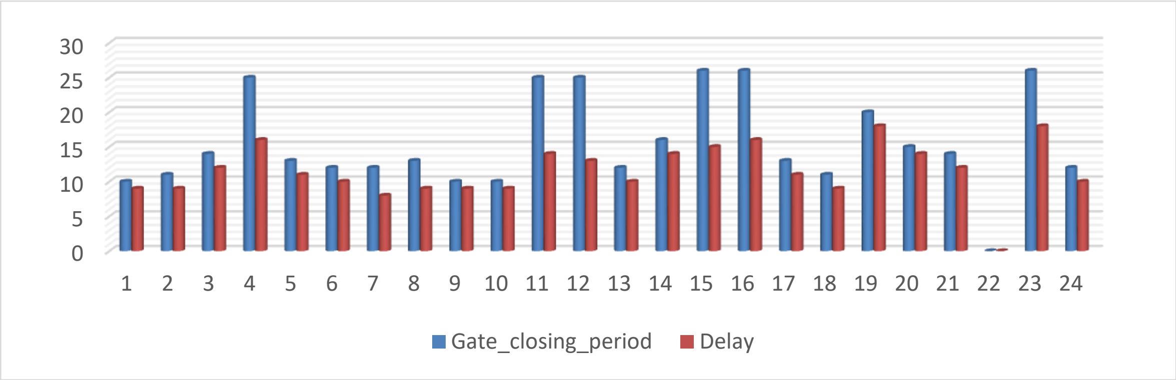


Figure 2.6. Barrier closure schedule and average daily delay time for vehicles

As a result, the railway barrier is almost always important. This means that before the train arrives, it will drop prematurely. The speed of approaching the train is also different. To reduce the waiting time at the intersection, you need to increase the speed of the train several times.

The calculation of traffic delays at the railway crossing per week is as follows. The value of column t indicates the t-test associated with testing the significance of the parameter shown in the first column. For example, a value of 2,743 t (Intercept) means that the t-test of 2,460 is divided by the standard error of this assumption, 0.896. Pr (> | t |) gives the value of R for that t -test (the ratio of the distribution of t in this df is greater than the absolute value of the statistic t). 0.00676 is a survey number, and the asterisks after Pr (> | t |) provide a visible way to estimate whether the statistics meet different A criteria.

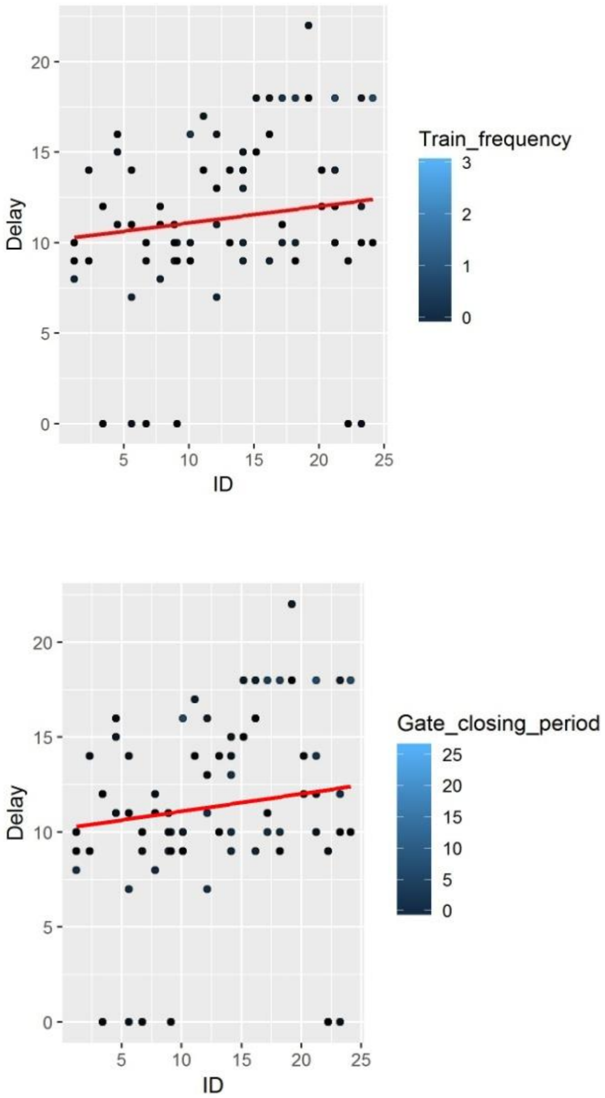


Figure 2.7. Calculate the weekly delay of a vehicle at a railway crossing. General comparison of traffic delays a) train frequency, b) traffic density, c) barrier closure period, d) rush hour

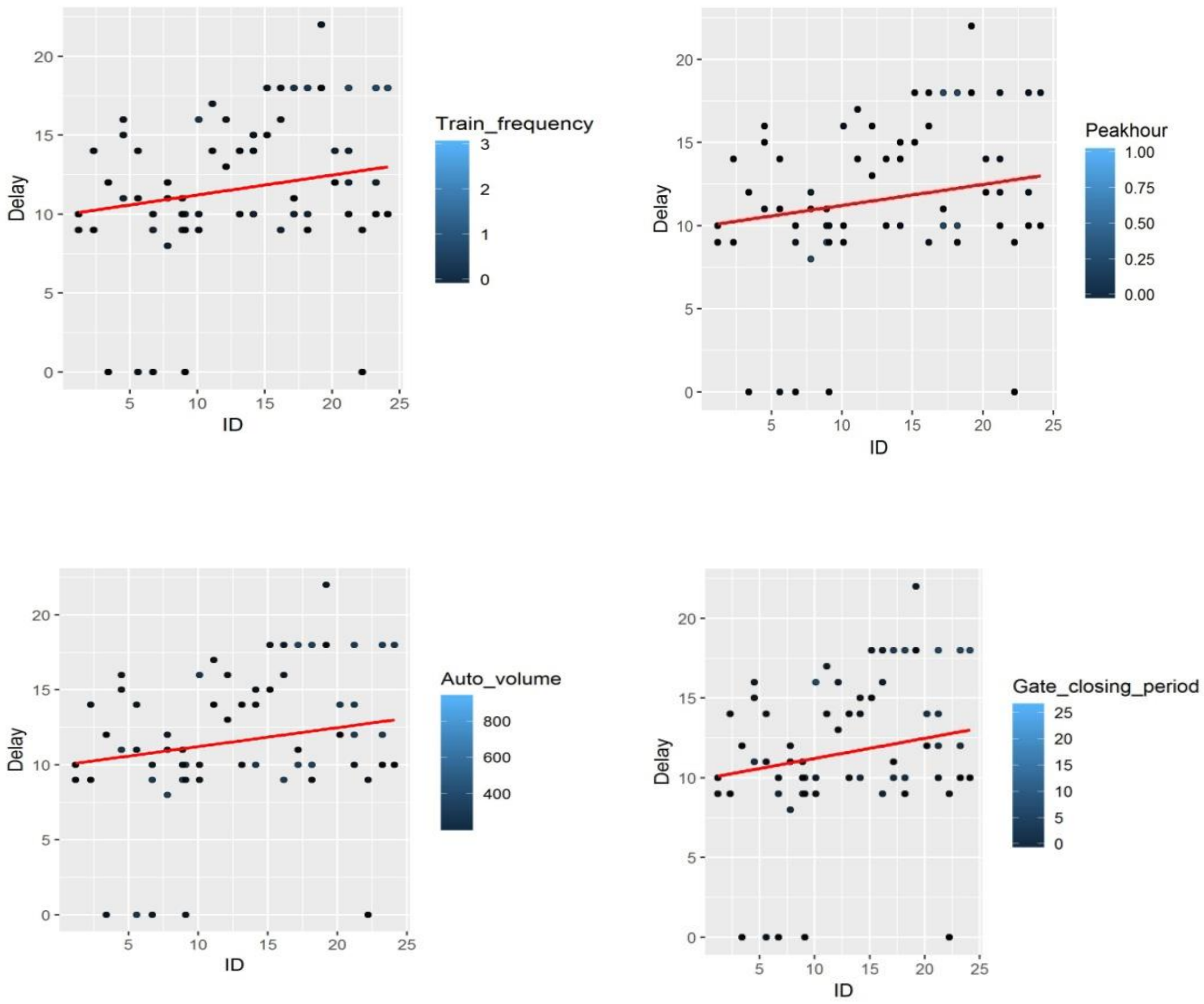


Figure 2.8. Calculate the delay of the vehicle on working days at the railway crossing. Comparison of vehicle delays during the working day, a) train frequency, b) rush hour, c) traffic flow, d) barrier closure period

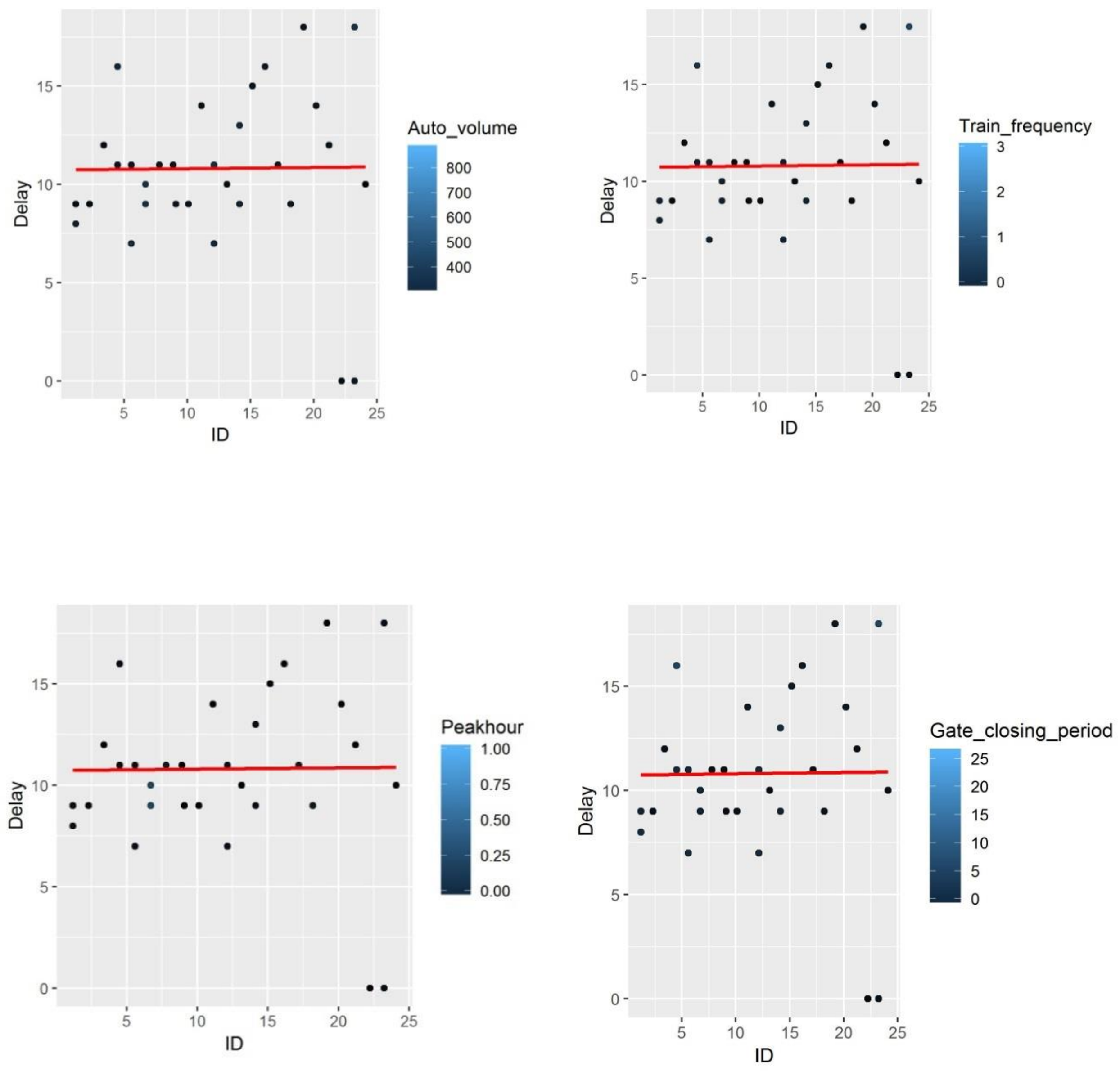


Figure 2.9. Calculate the weekend delay at the intersection. Comparison of vehicle delays at the end of the week with traffic flow volume, train frequency, rush hour, barrier closure period

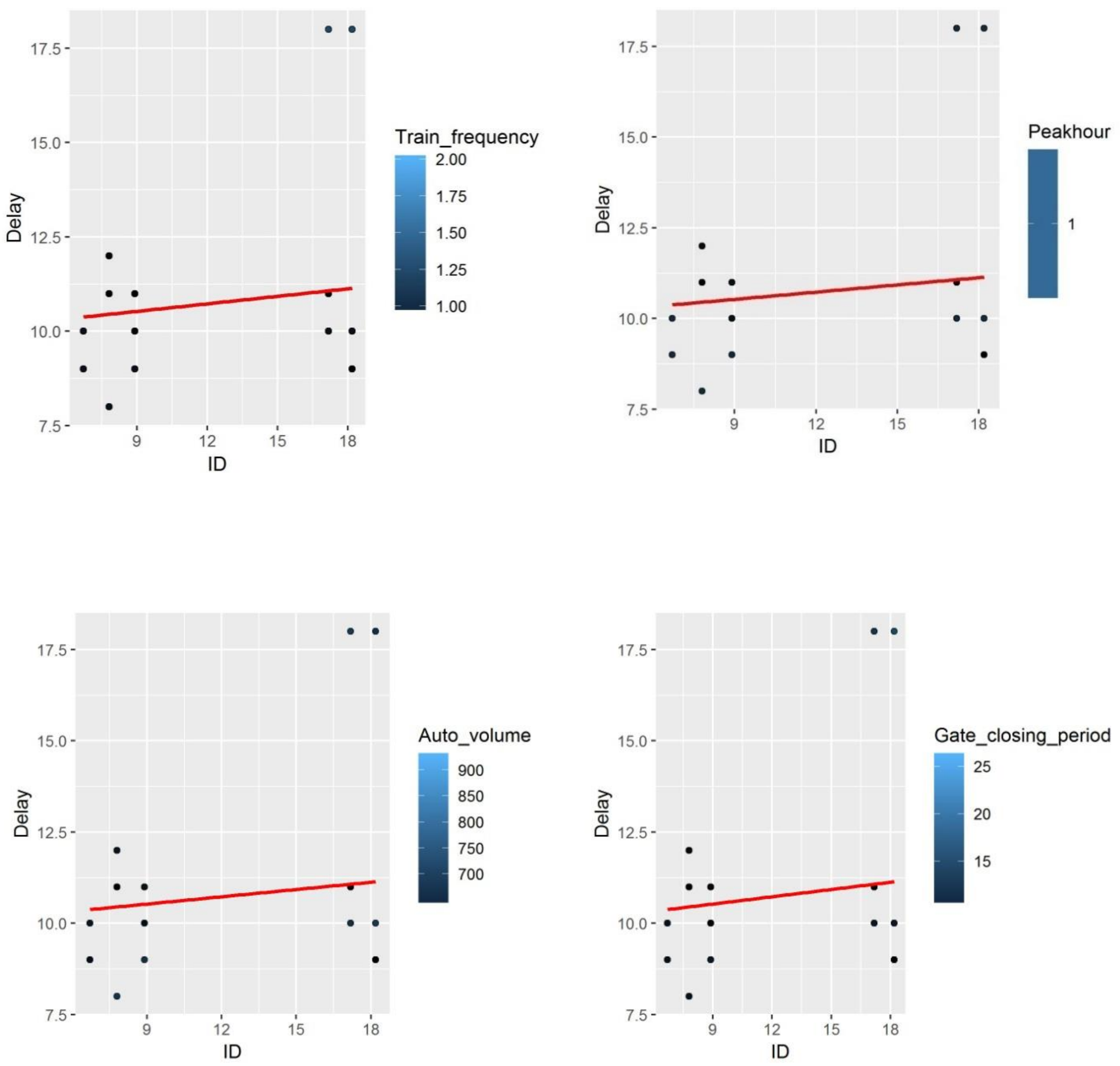


Figure 2.10. Calculation of traffic delays at intersections during rush hour. Comparison of vehicle delays at the end of the week with a) train frequency, b) rush hour, c) traffic flow, d) barrier closure period

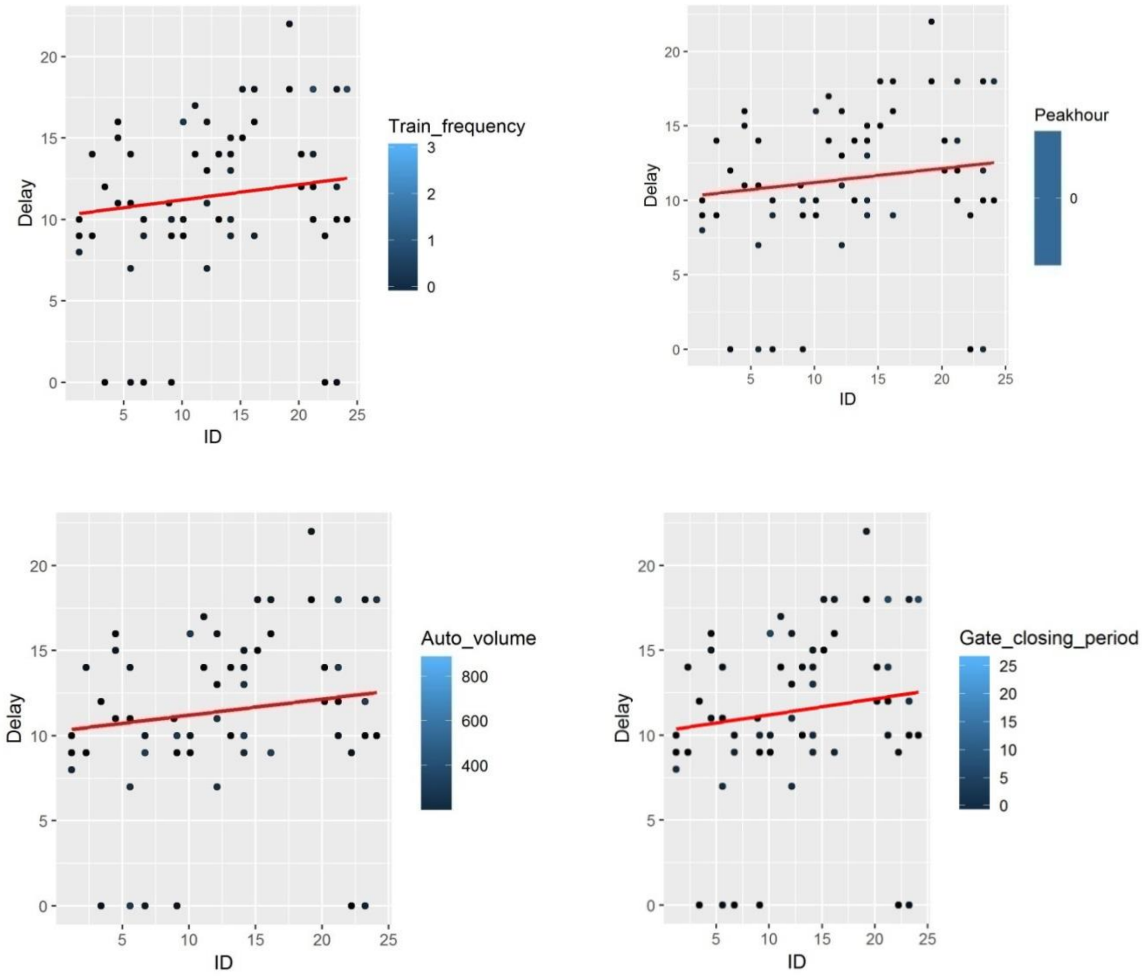


Figure 2.11. Calculate overtime delays at intersections.

Comparison of vehicle delays outside the peak period of the day,

a) train frequency, b) peak time, c) traffic flow,

d) barrier closure period

Table 9

Results of correlation analysis (t-test)

	General	**In a week**	**Week the end**	**Rush hour**	**With out rush hour**
Variable	Pr(>|t|)				
(Intercept)	**0.00676 ****	**0.0285***	**0.094961.**	0.7145	**0.0102 ***

Continuation of the table 9

Train frequency	**0.01875 ***	**0.0451***	0.235585	**0.0175 ***	**0.0508 .**
Auto. flow	0.71799	0.9412	0.662931	0.6631	0.7471
Rush hour	0.15978	0.1858	0.624845		
Barrier closing period	**5.62e-09*****	**3.09e-06*****	**0.000848 *****	0.3150	**3.5e-08 *****

Table 10

Results of correlation analysis (evaluation)

	General	**In a week**	**Week the end**	**Rush hour**	**With out rush hour**
Variable	Estimate				
(Intercept)	2.460115	2.6855614	2.2915399	1.059446	2.5319180
Train frequency.	1.748422	1.8670569	1.4772594	5.629356	1.5723432
Auto. flow	0.000480	0.0001268	0.0009982	0.001512	0.0004659
Rush hour	0.692729	0.8167885	0.4123783		
Barrier closing period.	0.415388	0.4098101	0.4181474	0.188392	0.4261248

Table 11

Model summary

Model	**R Square**	**Adjusted R Square**	**Std. error of the estimate**
1	0.793	0.788	2.07
2	0.789	0.782	2.18
3	0.805	0.787	1.84
4	0.806	0.781	1.06

Based on the data, the barrier is active for a total of 6 hours per day on a particular working day. As shown in Table 12, the rail barrier is active for 20% of the time during the rush hour hours of the working day, and when active it remains on average for 11 minutes. Table 12 shows that the crossing is active for most of the day, causing traffic delays [7].

Table 12

Weekdays and weekends are the time to close the barrier

Week and Weekend	Period	The number of barrier descents	Average barrier descent time (min)	Total landing time of the barrier (min)	General
Week	24 hour	31	12	371	25%
Week	Rush hour	4	11	49	20%
Week	With out rush hour	27	12	322	27%
Weekend	24 hour	29	11	347	24%
Weekend	Rush hour	4	13	52	22%
Weekend	With out rush hour	27	12	322	26%

* Period – a day of crossing the railway for 24 hours, Rush hour time – from 7:00 to 19:00, Rush hourless period from 9:00 to 5:00 and from 19:00 to 7:00 until.

* The number of barrier closures is the number of times the gate is active during a single day.

* Average minutes of closing the barrier - the average number of minutes the gate is active during the day.

* The total closing minutes of the barrier are the minutes when the gate is active at all times of the day.

In this case, 371 minutes is the total descent time of the barrier, what is the percentage per day? 24 hours a day, 1440 minutes per minute. Therefore, the total percentage t = (371 * 100) / (24 * 60).

Table 13

Results of correlation analysis

	Week (24 hour)	
	Estimate	Pr(>|t|)
(Intercept)	2.289008	0.5633
Train frequency.	1.006211	0.6029
Auto. flow	0.001007	0.8536
Rush hour	0.728962	0.5577
Barrier closing period.	0.465767	0.0152*

After changing the train frequency:

Table 14

Weekdays and weekends are the times when the barrier falls.

After the train frequency decreases

Week and Weekend	Period	The number of barrier descents	Average barrier descent time (min)	Total landing time of the barrier (min)	General
Week	24 hour	31 / 25	12 / 12	300	25% / 20%

From the tablet, when the train frequency was reduced to 5, the total "descent time" of the barrier was also reduced. At the same time, the time of lowering the railway barrier on weekdays was reduced by 5%.

Table 15

Results of correlation analysis

	Week (24 hour)	
	Estimate	Pr(>|t|)
(Intercept)	1.4881937	0.7159
Trainfreq.	2.2051497	0.2552
Auto. flow	0.0009069	0.8737
Rush hour	0.5711808	0.6619
Barrier closing period.	0.4291027	0.0133*

Table 16

Model summary

Model	R Square	Adjusted R Square	Std. error of the estimate
1	0.816	0.777	2.05
2	0.797	0.754	2.18

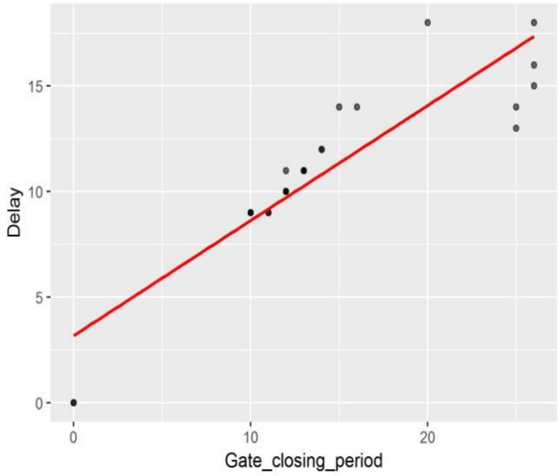


Figure 2.12. Weekdays and weekends are the time to close the barrier

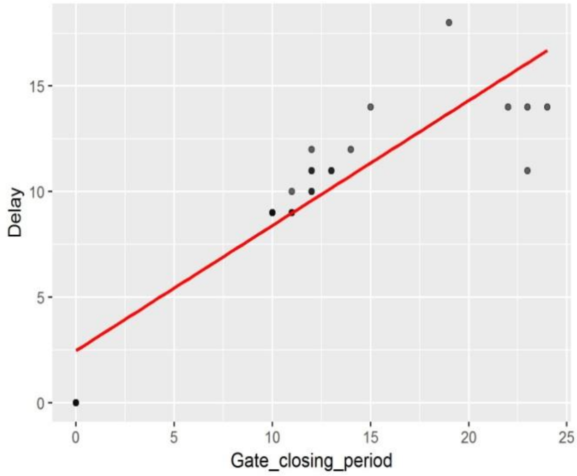


Figure 2.13. Weekdays and weekends are the time to close the barrier. After the train frequency decreases

Discussion on research findings and limitations. The results show that the coefficients of each variable are positive for the delay in crossing the railway, which indicates that they are interrelated, with the exception of traffic and car hours. As the frequency of trains increases, the number of railway crossings increases, the delay in closing the barrier increases, and theoretically a positive infinity is reached. The frequency of trains mainly affects the delay of the crossing. During rush hour, when the volume of trains increases by 1 train, the delay of wagons increases by 8 minutes. There are two categories of waiting time for road users: the time before the train arrives at the crossing and the time when the train leaves the intersection. Studies have identified a variety of factors that determine whether users consider waiting times to be “acceptable” [16]. There is no set amount of waiting time that is critical to the level of nervousness of road users or that can lead to dangerous behaviors. The results of the study show that due to the lack of trains and warning signals, the majority of traffic users try to cross the crossing. Experience using crosswalks with incorrect warning devices can also lead to dangerous behaviors.

From the table, if we reduce the frequency of movement of the train, then we get a positive result of 5%. As a result, the frequency of the train will be positive. Hence, it is necessary to reduce the frequency of movement of the train. No train should be scheduled in the Rush time. Then there will be no traffic on the roads.

The case studies presented in this study are limited to only one area. Vehicle speed does not include analysis. However, the queuing of vehicles at the railway crossing and the speed of the train, as well as the length of the train were not taken into account.

The interval between the closing of the barrier at the railway crossing is of great importance for the delay of vehicles. This means that the speed of the train affects the waiting time. Another important factor is the frequency of trains. The study summarizes the importance of the V2I system for improving intersection crossings in the study area [28]. The introduction of this system will help reduce the waiting time of the vehicle. Crossing is unpredictable. The arrival of the train at the intersection at rush hour had a negative impact on the barrier closure period. The analysis shows that the barrier closure period, the frequency of trains, shows that this thesis determines the importance of the introduction of the V2I system [15]. The research also provides and provides specific theoretical support for traffic management and control.

Conclusions

1. Parameters related to automated devices and vehicles to ensure safety in the operation of railway crossings were collected, a parametric research algorithm for the causes of delays of vehicles was developed and a model was selected.

2. Objects located in the study area and the factors influencing them were collected. Delays were detected on weekdays, weekends, as well as during the rush hour and free hours of the day in front of the intersection of vehicles.

3. The frequency of operation of the barrier at the intersection and the frequencies of the train, the number of stops and the structure of vehicles are provided on the basis of a graph model of clarity and high formality.

4. During the week, on weekends, as well as during rush hour hours of the day and during rush hour hours, the delay of vehicles at the railway crossing was studied on the basis of a graph model.

5. The results of the correlation analysis were obtained by evaluating the results of the t-test and correlation analysis, and simulation results that provided research and design based on the model's conclusions.

6. In the end, the frequency of trains was reduced by 5%, the total "descent time" of the barrier was reduced. At the same time, the time of the railway barrier descent on weekdays was reduced by 5%, and congestion at the intersection was reduced as a result of the positive growth of the model.

CHAPTER III.

MODELS AND METHODS OF SENSORS FOR MONITORING TRAIN TRAINING AT RAILWAYS

3.1. Selection of sensors to monitor the approach of the train to the railway crossing

3.1.1. A method of controlling the crossing of a train by rail chains using insulating joints

Notification of the approach of the train to the crossing is transmitted by means of automatic locking rails. The block chain inside the intersection will be separated by a rail chain. The allotted space is the intersection [22]. A portion of the rail chain is used to guide the train to form an approach section.

When the train enters the approach section, the intersection is closed. The second part of the rail chain, located along the intersection, is used to organize the train in the direction of exit from the intersection or as an approaching section in the odd direction [36]. The intersection is opened from the moment the train leaves the approach section and is in the departure section.

Depending on the location of the intersection in the block section, the calculation of the length of the approach section is determined in accordance with Figure 3.2 [22].

If the crossing is located at a distance equal to the approximate length of the 5 L_{P} approach from the auto-blocking stoplight, then the actual length of the L_f approach is equal to L_{P} (Figure 3.3).

In this case, a warning is issued to close the intersection for a single approach area. When the intersection is close to stoplight 5, the calculated length $L_{\text{Р}}$ is longer than the distance to this stoplight. In this case, the approach area is located between traffic lights 5 and 7 (Figure 3.3, b). Now the actual length of the approach section is calculated from 7 traffic lights, and two approach sections are formed: the first from the intersection to 5 traffic lights, and the second between traffic lights 5 and 7. In this case, a warning to close the intersection is sent to the two approach points [22].

In some cases, when there are two approaching sections, their actual length is greater than calculated, and the additional length is obtained $\Delta L = L_{\text{ф}} - L_{\text{Р}}$, which leads to early closure of the intersection and delay of vehicles. To equalize the lengths $L_{\text{Р}}$ and L_f, it is necessary to cut the rail chain between the stoplights 5 and 7 and form an approach section from the intersection. Because this requires the use of additional equipment and complicates automatic locking, the rail chain is not interrupted and time delay elements are incorporated into automatic intersection signaling devices [51].

With the help of these elements, the delay to close the crossing is activated from the moment the train enters the second approach section. This delay is equal to the travel time of the train traveling between the section at maximum speed and the difference between the actual and calculated length of the approach section. It closes at a later date and increases the notification time for trains traveling below the maximum speed of the intersection [22].

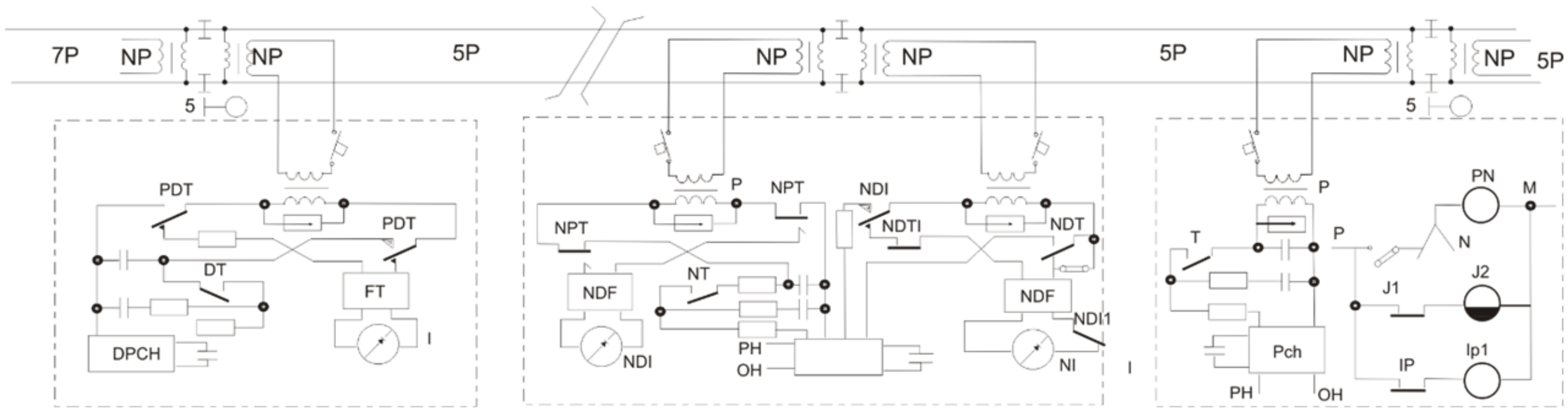


Figure 3.1. Automatic signal control scheme for two-way automatic blocking in alternating current [7, 22]

Disadvantages of the system:

1. The train interval causes 40% of the faults in the control system in the path of the insulated joints.

2. Lack of train approach speed control

3. When there are two approaching sections, their actual length is greater than calculated, and the additional length is obtained uzunlik $\Delta L = L_{\Phi} - L_{P}$, which leads to early closure of the intersection and delay of vehicles.

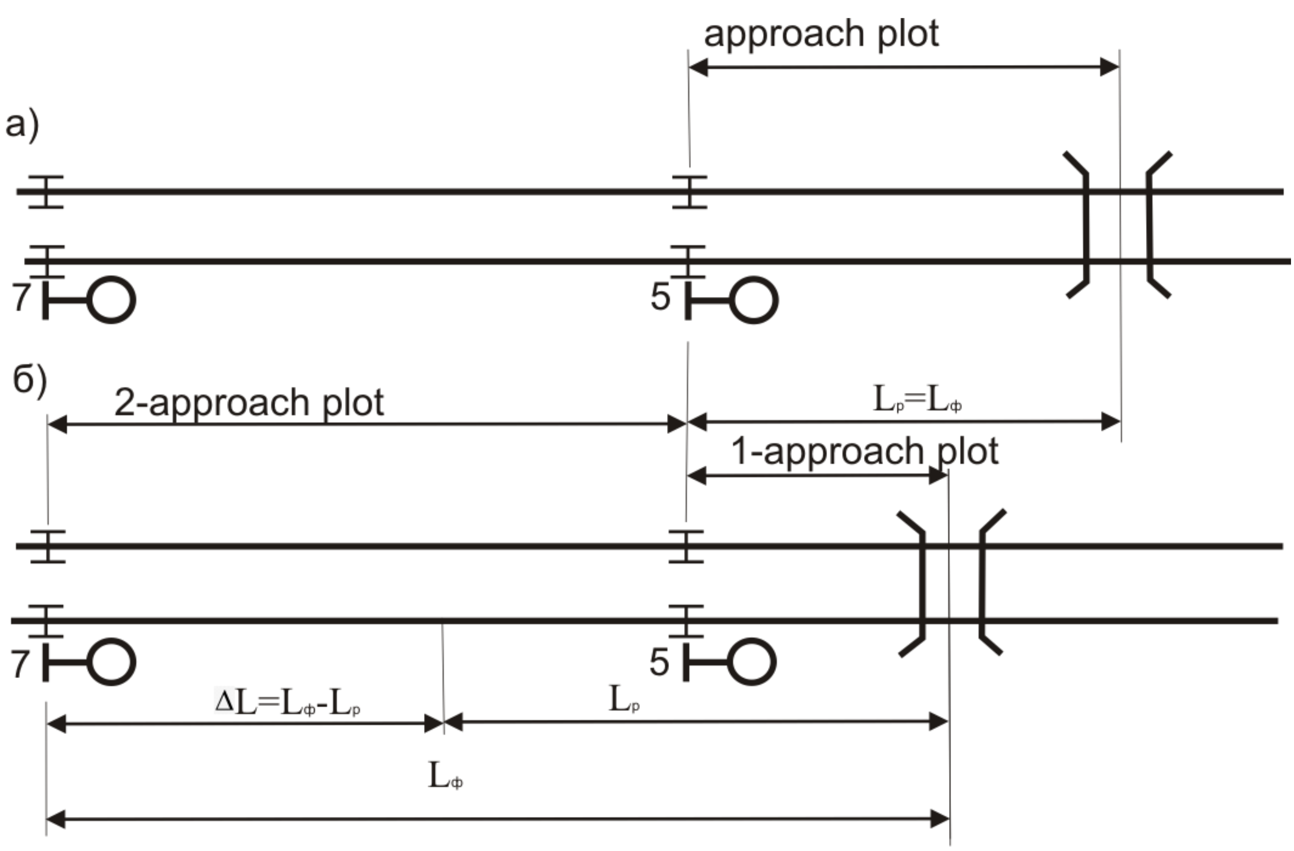


Figure 3.2. The approach area in front of the intersection scheme for detection [22]

3.2. An arrow counter is a method of controlling the approach of a train to a railway crossing

Microprocessor Automated Crossing Alarm System (MP-AKS) system is equipped with all types of road blocking devices located on single-lane and multi-lane hauls at the intersections with and without duty (as well as semi-automatic (YAAB) and automatic (AB)), designed for use with all types of train traction and rail types [40].

Microprocessor-based automated intersection signaling system K1HP ... K4HP four computing points, control device located in the intersection relay cabinet (RSH MP-AKS – Relay cabinet-automatic intersection signaling) RSH MP-AKS (XBU computing-control equipment) and station equipment (Figure 3.3).

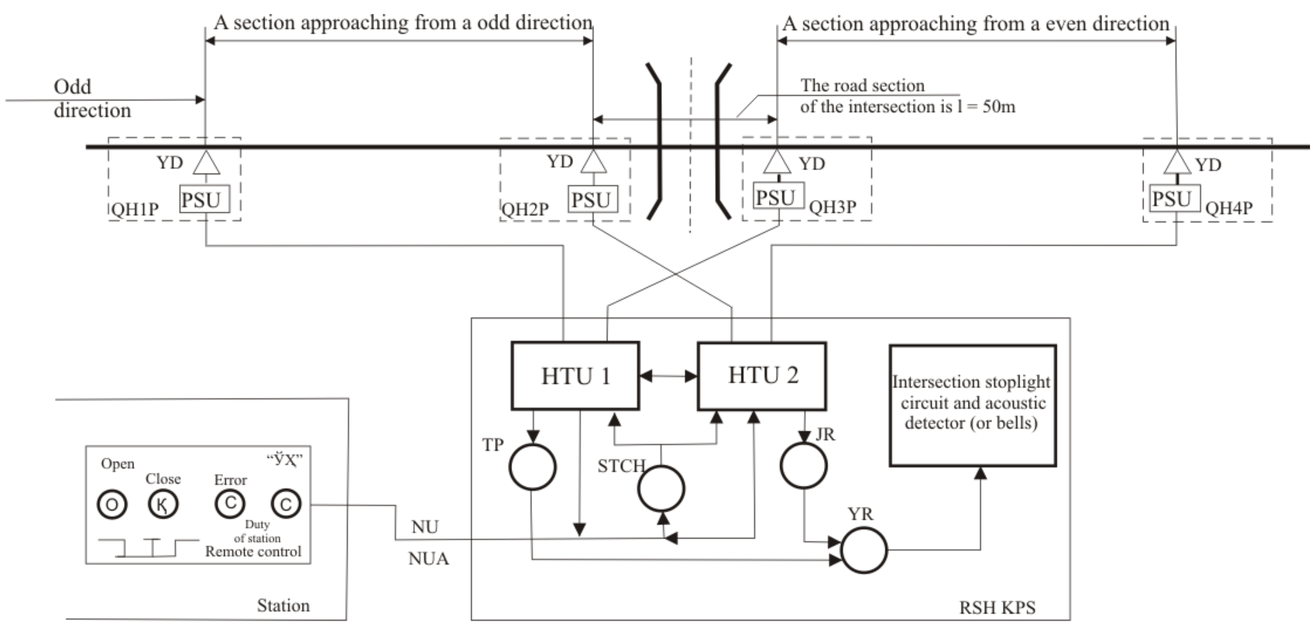


Figure 3.3. MP-AKS device at one-way intersection block diagram

Each metering point of the KH1P-KH4P devices includes a floor-mounted signal converter with a YD-path sensor and a PSO sensor located next to the sensor in the cable box. The path sensor detects the passage of moving content axes through the control zones, while generating high-frequency electrical signals, converting them to PSO 'frequency and amplitude, calculating them HTO'1 and HTO'2 via signal cable devices. The transmission of control signals from the station to the intersection, as well as the exchange of control data between the station and the intersection is carried out via the NU-NUA line, which can also be used fiber-optic communication line (OTAL) [69].

The control unit of the MP-AKS system operates on the basis of a strict algorithm defined by the program code embedded in the memory of SRP-type computing devices during their production.

The MP-AKS control unit provides the following functions:

- control of the condition of the approach / gap, as well as the road section of the crossing (hereinafter referred to as the intersection);

- control of attached relays (TR or JR) in crossing signaling;

- control of flashing relay indicators of traffic lights at the intersection;

- control of the operation of the flashing relay indicators of traffic lights at the intersection;

- monitoring of technical condition of crossing signaling devices;

- Forming control information on the status of MP-AKS devices, delivering it to the nearest station (responsible for this intersection) and displaying it on the control panel of the station duty officer;

- Regular diagnostics and testing of nodes and modules that are part of the computing technology to detect hardware failures or software failures;

- real-time collection and archiving of information on train status and changes in the condition of MP-AKS equipment to the registrar and transfer of this information to remote monitoring systems;

- switching from the composition of computing and solving equipment to the protective (safe) state of the system in case of failure of any node or module;

- Automatic system reset (DHAT) after a malfunction;

- the ability to artificially restore the system to its original state (DHST) after failure or transfer of devices to protection mode;

- switching to protection mode, if it is in the process of DHAT or DHST circuits connected to EM or AB devices, approaching the intersection of the detected train [21].

TR and JR relays are designed to detect the presence of a train at the approaching sections of the crossing and to control the operation of the main switching relay YOR and its YOR1 repeater. The control of the clearance of the road sections at the intersection is carried out by the method of calculating the axes of the rolling stock [31].

For example, the position of the odd approximation section is controlled by the HTO’1 device by comparing the results of the axis calculations in KH1P and KH3P. In the absence of trains and in the technical condition of the controls and at the checkpoints, the TR and JR relay armatures will be raised. The TR (JR) relay is switched off when the movement of the intersection on the road section and the approach of the odd (even) train from the odd (even) direction is observed. In addition to Heren, the TR (JR) relay must be de-energized. If the road section of the intersection in the odd (even) direction is vacated, the employment of the distance section will be maintained for a long time. The start time interval of the re-intersection alarm is [31].

The main switching relay YOR and YOR1 are designed to turn on traffic lights and audible alarms (standard solutions for APS).

To execute IVIS commands, the IVL relay transmits the IVIS commands designed and received to the HTO'1 and HTO'2 computing devices.

Prior to commissioning, the counting and control devices must be returned to their original position by the coordinated actions of the station attendant near the intersection and the SMB electromechanic of the signaling and control system at the intersection [31].

Station devices provide the following functions:

- Intersection monitoring;

- control of technical condition of rolling stock axes;

- Manage the process of artificially restoring the system to its original state (DHST) after performing or failing scheduled work, or managing the operation of system devices.

Ensure control of the intersection using the indicators "OPEN", "CLOSED" and "FAILURE", the technical condition of the axis counting devices is monitored using the indicator “OH”. The indicators are located on the SN panel. The artificial reduction of the system to its original state is performed using the IVPK button, which is also mounted on the SN remote control. Intersection of empty road sections at the intersection is carried out using HTO'1 and HTO'2 computing devices.

Let's look at the operation of the MP-AKS in the example of a single-lane intersection without a duty officer (see Figure 3.3).

In the first case, there is no rolling stock on all sections of the intersection, intersection traffic lights are off, acoustic detectors are off, the intersection is open for traffic.

In the ACS relay cabinet:

- TR and JR, YOR and YOR1 ignition relays are on;

- artificial reset of the linear relay STCH computing equipment is disabled.

The SN control panel is lit with a white “ON” indicator, the yellow “NOSOZ” and “OH” indicators are yellow and the red “CLOSED” indicator is off.

The YD sensor turns off the TR relay at the input of the first axis of the odd train for the calculation point KH1P computing-analytical meter HTO’1. This, in turn, turns off the YOR and YOR1 relays, whose contacts turn on the red flashing lights of the intersection stoplights and acoustic detectors.

The HTO’1 computational analyzer continuously compares the number of bullets entering the area bounded by the sensors KH1P and KH3P with the number of bullets leaving it. After the last axis of the train travels along the track sensor of point KH3P, the data at the calculation points KH1P and KH3P will be the same and the TR relay will be supported. If these numbers match (equal), then the HTO’1 computing device turns on the TR relay – the intersection alarm is turned off.

When a single-track train travels along the distance section (between KH2P and KH4P), the distance section, which is occupied by the HTO’2 calculation and analysis, calculates the time. If the employment of the distance section remains after the expiration of the estimated time interval entered in their memory during the manufacture of the computing devices, the HTO’2 device turns off the JR relay, which ensures that the intersection alarm is turned on again [31]. If the train clears the section before the scheduled time, the intersection will not be closed again.

When a double-track train is traveling, the intersection alarm is activated and deactivated when the first bullet enters the KH4P point sensor area - after the “tail” of the train (last arrow) the KH2P travel sensor enters, exits and exits provided that the number of arrows is the same. and it goes off – after the "tail" of the train (the last bullet) walks with the KH2P track sensor, provided that the number of bullets entering and exiting is the same.

The APS-MP system provides logic tracking control at the intersection train at the application level. If this procedure is violated for any reason, then the intersection is opened and the traffic light is turned off and the acoustic signals are given after the long tail sensor of the train "tail" KH4P or KH1P (when the train is moving in the opposite direction). occurs.

Defective bullet counter:

1. Lack of railway track control
2. Non-fixation of the closing time at the intersection
3. Lack of train speed control
4. Influence of weather conditions
5. Unstable arrow count

3.3. A method of controlling the crossing of a train by rail chains using uninsulated joints

To overcome the above shortcomings, it is recommended to use standard devices to control the approach of the train to the intersection, to use continuous railway chains with a tonal frequency current receiver (Figure 3.4), ie the rails are inductively connected to the track lines case. With this connection, the control sensor, which detects the TP1 current path receiver, is located at the input boundary and at the location of the receiving path coils.

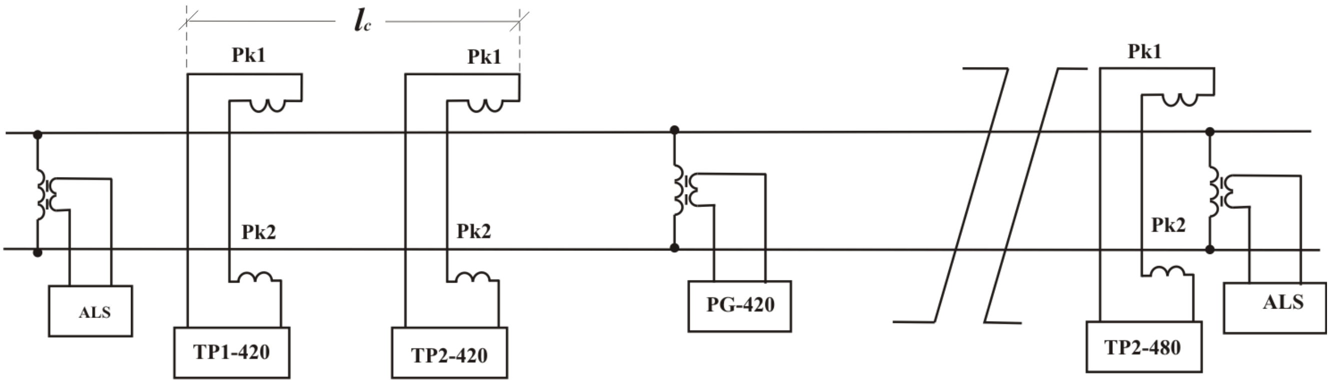


Figure 3.4. Schematic of a control sensor with a current receiver

TP1 – current receiver 1

TP2 – current receiver 2

TP3 – current receiver 3

PG-road generator

In the idle state of the controlled section, the track section current is powered by the driving force PK1 and PK2 coil receivers direct signal current along the rails along the rails and for the oncoming train control sensor The current over the receiver does not affect the current flows across the receiver, and conversely, even this current amplifies the current. Once the first wheels of the train have passed through the receiving roller connection, the current begins to flow mainly through the set of wheels, and the current on the receiving rollers decreases, which eliminates the power of the track receiver. Leads to hardening and installation of access to the train on the controlled part.

In addition to heren, it is recommended to use a current receiver TP2 installed at a distance lc to determine the speed at which the train approaches the intersection.

The current receiver TP1 controls the entrance of the train approaching the intersection, the current receiver TP2 is used to determine the speed of approach of the train and TP3 is used to control the exit of the train from the intersection.

When the train enters the approaching part of the intersection, the current receiver TP1 is powered and sends a signal to the approaching microcontroller of the approaching train. The microcontroller triggers a timer to determine if the train is going to TP2 on the second track. When the head of the train enters the TP2, the signal enters the microcontroller, and the timer stops. From the time the train travels along section lc, the speed of the train is determined and then the closing time of the intersection is calculated. The departure of the train from the intersection zone is determined by the TP3 current receiver.

3.4. Development of a program and algorithm for determining the optimal parameters of control sensors approaching a railway crossing

3.4.1. Mathematical model of a sensor to control the approach of a train to a railway crossing in normal mode

This paragraph describes the stopping distances of high-speed trains and freight trains with maximum weight during emergency and service braking, as well as the length of the sections approaching the intersection. A speed control sensor using tonal rail chains with current receivers was selected.

To determine the optimal parameters of the rail chain, its study should be carried out in normal, shunt and control basic operating modes. To study the operation of a tonal rail chain with a current receiver in normal and shunt modes, we use the formula of sensitivity criteria for a normative shunt known from the theory of rail chains:

$$К_{shn} = \frac{Z_{psh}}{\frac{К_{z} * U_{max}}{К_{v} * U_{min}} * Z_{pr}} \geq 1, \quad (3.1)$$

where Z_{psh} – Shunt transmission resistance with shunting sensitivity;

Z_{pr} – the signal resistance of the tonal rail chain with a current receiver in normal mode;

U_{max} – the maximum power supply value of the rail chain;

U_{min} – the minimum power supply value of the rail chain;

K_z – the receiver's reserve factor;

K_v – the rate of return of the receiver.

In the form of a circuit diagram with a current receiver (Fig. 3.7) we imagine the scheme of the tonal rail chain and derive the equation of the sensitivity criterion with respect to the normative shunt K_{shn}.

There are two unknowns in this expression:Z_{psh} and Z_{pr}.

Z_{pr} to obtain an analytical expression, we present the tonal rail chain in the form of a circuit diagram (Figure 3.7).

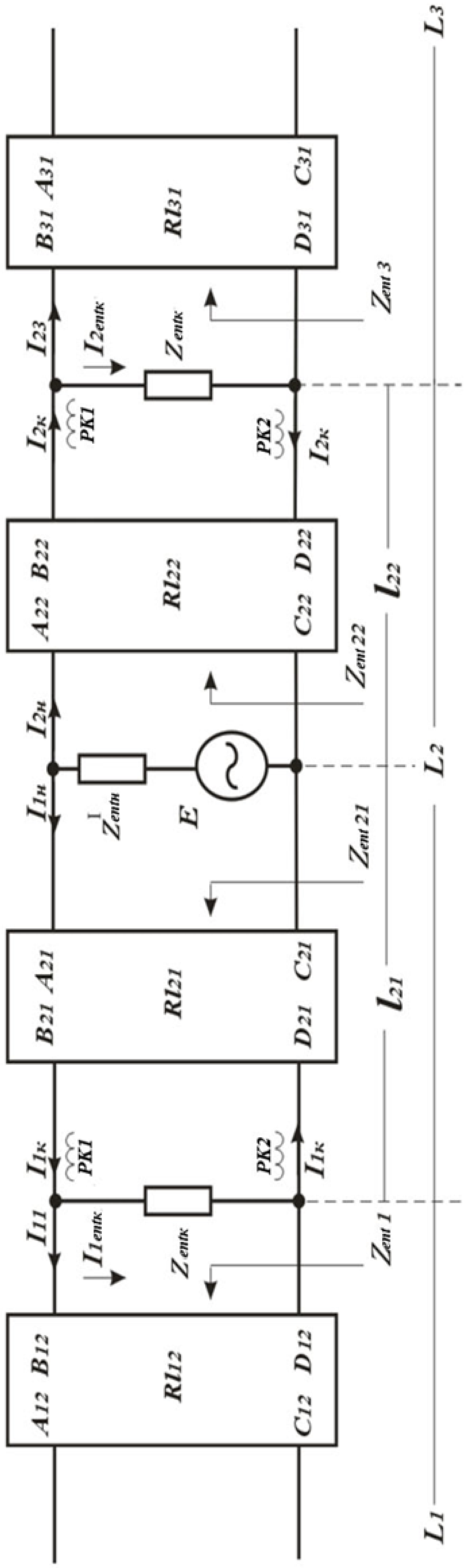


Figure 3.7. Scheme of replacement of the tonal rail chain with current receivers in normal mode

where Rl12, Rl21, Rl22 and Rl31 are the four-pole railway lines within the rail chain under study and the adjacent rail chains, respectively;

Z_{vxk} – Input resistance of ALS device hardware

Z^{I}_{vxn} – the reverse input resistance of the apparatus of the feeding end of the rail chain;

Z_{vx1} – L_1 the input resistance of an adjacent rail chain;

Z_{vx3} – L_3 the input resistance of an adjacent rail chain;

Z_{vx21} – l_{21} the input resistance of the rail chain under study;

Z_{vx22} - l_{22} the input resistance of the rail chain under study;

PK1, PK2 – an inductance coil that is installed at the boundaries of the rail chain under the rail;

I_{1n} , I_{2n} , I_{1k} , I_{2k} – currents at the beginning and end of the rail chain, respectively.

At high signal current frequencies of adjacent rail chains Z_{vx1} and Z_{vx3}, the input resistance can be replaced by the wave resistance Z_{v1} va Z_{v3}, and we also change it for the convenience of calculations, for example, its input resistance Z_{vx22} ng side, in which case the appearance of Figure 3.7 is as follows:

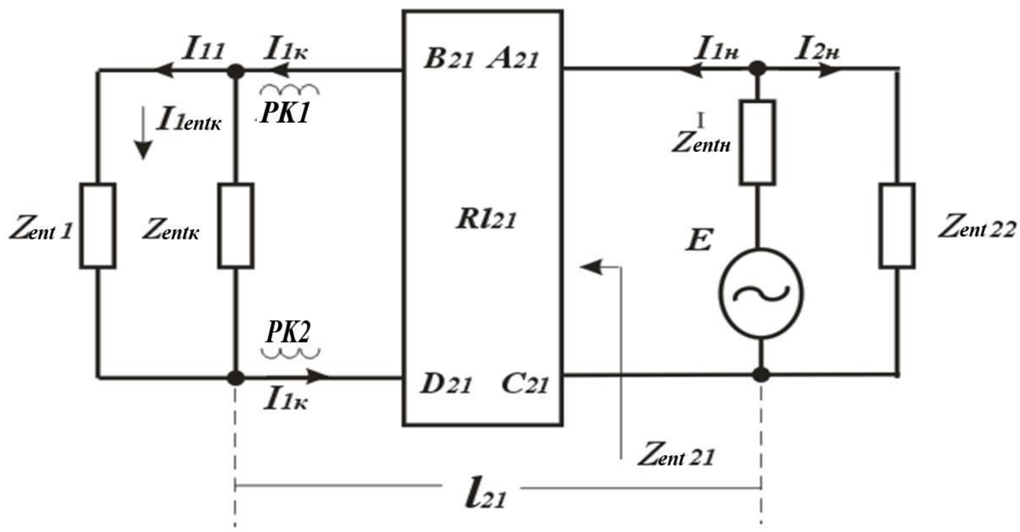


Figure 3.8. Wave resistance switching scheme

$$Z_{vx22} = \frac{A_{22}*\left(\frac{Z_{vxk}*z_{v3}}{Z_{vxk}+z_{v3}}\right)+B_{22}}{C_{22}\left(\frac{Z_{vxk}*z_{v3}}{Z_{vxk}+z_{v3}}\right)+D_{22}} = \frac{ch\gamma_{22}l_{22}*\left(\frac{Z_{vxk}*z_{v3}}{Z_{vxk}+z_{v3}}\right)+z_{v22}sh\gamma_{22}\,l_{22}}{\frac{1}{z_{v22}}sh\gamma_{22}\,l_{22}\left(\frac{Z_{vxk}*z_{v3}}{Z_{vxk}+z_{v3}}\right)+ch\gamma_{22}l_{22}}. \quad (3.2)$$

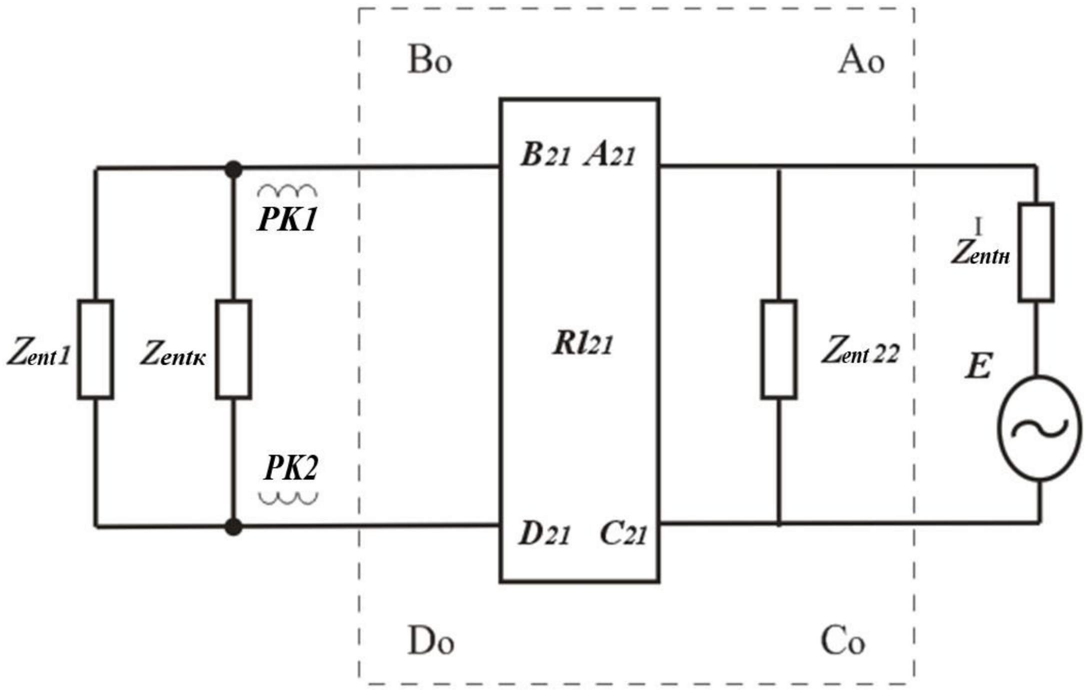


Figure 3.9. General scheme of replacement of the tonal rail chain in normal mode

where Ao, Bo, Co, and Do are the common coefficients of the four poles of the rails, which can be determined by.

$$\begin{vmatrix} A_0 & B_0 \\ C_0 & D_0 \end{vmatrix} = \begin{vmatrix} 1 & 0 \\ \frac{1}{Z_{vx22}} & 1 \end{vmatrix} * \begin{vmatrix} A_{21} & B_{21} \\ C_{21} & D_{21} \end{vmatrix} = \begin{vmatrix} A_{21} & B_{21} \\ C_{21}+\frac{A_{21}}{Z_{vx22}} & D_{21}+\frac{B_{21}}{Z_{vx22}} \end{vmatrix} \quad (3.3)$$

$$A_{21} = ch\gamma_{21}l_{21}\,, B_{21} = z_{21}sh\gamma_{21}l_{21}, C_{21} = \frac{1}{z_{21}}sh\gamma_{21}l_{21}, D_{21} = ch\gamma_{21}l_{21}.$$

from here

$$A_0 = ch\gamma_{21}l_{21}, B_0 = z_{21}sh\gamma_{21}l_{21},\ C_0 = \frac{1}{z_{21}}sh\gamma_{21}l_{21}, + \frac{ch\gamma_{21}l_{21}}{Z_{x22}},$$

$$D_0 = ch\gamma_{21}l_{21} + \frac{z_{21}sh\gamma_{21}l_{21}}{Z_{vx22}}. \quad (3.4)$$

In normal mode, the signal resistance is determined by the following formula:

$$Z_{pr} = A_0 * \frac{z_{vxk} * z_{v1}}{z_{vxk} + z_{v1}} + B_0 + Z^I_{vxn}(C_0 * \frac{z_{vxk} * z_{v1}}{z_{vxk} + z_{v1}} + D_0). \qquad (3.5)$$

Since the shunt mode is determined under the worst conditions for a given mode, i.e. when the voltage at the supply end of the rail chain is equal to its maximum value – Umax, the specific resistance of the Zr iron ring is equal to its minimum value and the maximum value of ballast resistance is rimax. If so, then the electron (Figure 3.8) can be represented in the form of an equivalent chain (Figure 3.10).

Now this circuit, with the built-in shunt, can determine the resistance Zpsh.

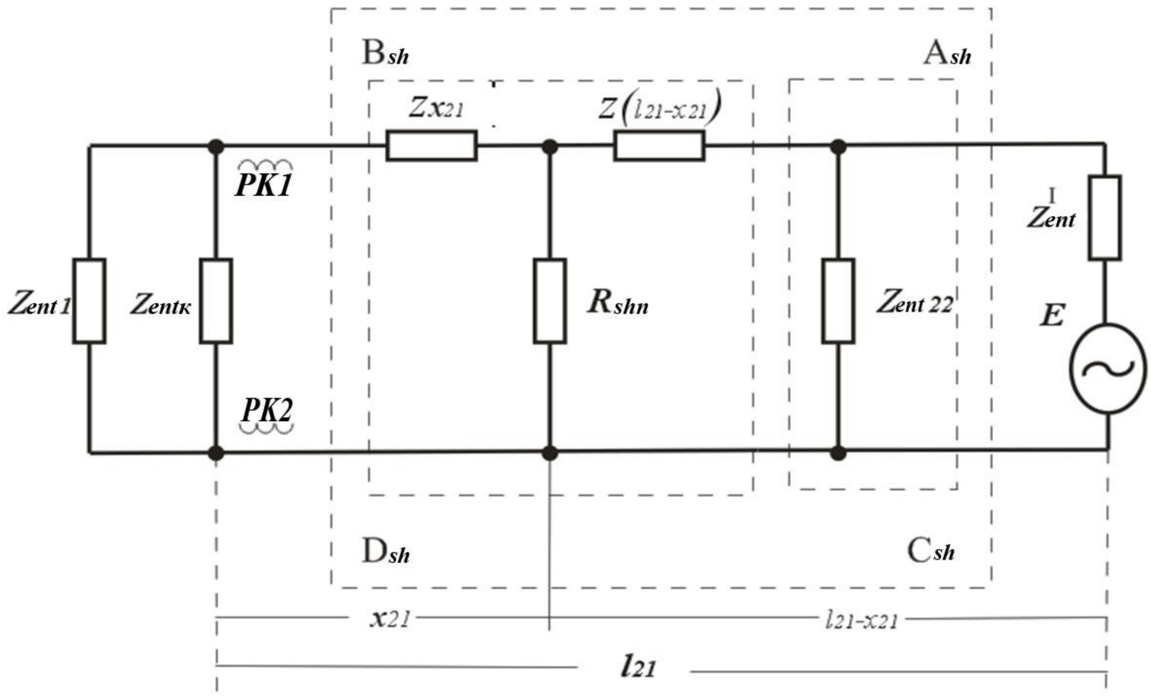


Figure 3.10. General scheme of replacement of the tonal rail chain in shunt mode

where Ash, Bsh, Csh, and Dsh are the common coefficients of the four poles of the rail in the shunt mode, which can be defined by the following expression:

$$\begin{vmatrix} A_{sh} & B_{sh} \\ C_{sh} & D_{sh} \end{vmatrix} = \begin{vmatrix} 1 & 0 \\ \frac{1}{Z_{vx22}} & 1 \end{vmatrix} * \begin{vmatrix} 1+\frac{z(l_{21}-x_{21})}{R_{shn}} & z(l_{21}-x_{21})+zx_{21}+\frac{zx_{21}z(l_{21}-x_{21})}{R_{shn}} \\ \frac{1}{R_{shn}} & 1+\frac{zx_{21}}{R_{shn}} \end{vmatrix} \quad (3.6)$$

$$A_{sh} = 1+\frac{z(l_{21}-x_{21})}{R_{shn}}, \quad (3.7)$$

$$B_{sh} = z(l_{21}-x_{21})+zx_{21}+\frac{zx_{21}z(l_{21}-x_{21})}{R_{shn}}, \quad (3.8)$$

$$C_{sh} = \frac{1}{Z_{vx22}} * \left(1+\frac{z(l_{21}-x_{21})}{R_{shn}}\right)+\frac{1}{R_{shn}}, \quad (3.9)$$

$$D_{sh} = \frac{1}{Z_{vx22}} * (z(l_{21}-x_{21})+zx_{21}+\frac{zx_{21}z(l_{21}-x_{21})}{R_{shn}})+1+\frac{zx_{21}}{R_{shn}}. \quad (3.10)$$

In shunt mode, the signal resistance is determined by the following formula:

$$Z_{psh} = A_{sh} * \frac{z_{vxk} * z_{v1}}{z_{vxk}+z_{v1}} + B_{sh} + Z^{I}_{vxn}(C_{sh} * \frac{Z_{vxk} * z_{v1}}{Z_{vxk}+z_{v1}} + D_{sh}). \quad (3.11)$$

Substituting (3.5) and (3.11) into Equation (3.1), we obtain the value of the sensitivity criterion for the normative shunt of the tonal rail chain with the current receiver:

$$К_{shn} = \frac{A_{sh} * \frac{z_{vxk} * z_{v1}}{Z_{vxk}+z_{v1}} + B_{sh} + Z^{I}_{vxn}(C_{sh} * \frac{Z_{vxk} * z_{v1}}{Z_{vxk}+z_{v1}} + D_{sh})}{\frac{К_{v} * U_{max}}{К_{v} * U_{min}} * (A_0 * \frac{Z_{vxk} * z_{v1}}{Z_{vxk}+z_{v1}} + B_0 + Z^{I}_{vxn}(C_0 * \frac{Z_{vxk} * z_{v1}}{Z_{vxk}+z_{v1}} + D_0)} \geq 1. \quad (3.12)$$

This expression is the basis for determining the maximum allowable length and optimal resistances at the ends of the rail chain.

3.5. Algorithm for determining the optimal parameters of the control sensor in normal and shunt modes

Using algorithm (3.12), an algorithm (Figure 3.7) was developed based on the condition of providing a shunt mode, a program was developed, and computer research was conducted. The algorithm for determining the optimal length of the railway section monitoring sensor is shown in Figure 3.7.

1 ÷ 5 operators form and send contacts on the cycle counters to arrange the maximum allowable position of the variables and the resistance at the end of the control sensor, the length of the control sensor, the insulation resistance of the rail, the lengths of the various control sensors of the current frequency.

Operators 6 and 7 calculate the values of Z_{potmin} and Z_{poshnt}, respectively, and K_{shnt} passes control to 8 operators to calculate the sensitivity criterion for the standard shunt, if the calculation result is zero or greater, then the shunt effect is considered, and this result for all variables are printed, if the result of the calculation is less than one, then these parameters do not provide a shunt effect and control is transferred to the operator 11, which for the parameter Z^{I}_{vxn} changes the contents of the cycle counter to one, it which analyzes to zero, and if the contents of the loop counter are not equal to zero, it changes this parameter by the value of the step and passes control to operators 6 and 7 to calculate the new values of Z_{potmin} and Z_{poshnt}. After enumerating all the values of Z^{I}_{vxn} In, control is passed to the operator 13, which changes the contents of the loop counter one by one with the parameter ϕ_{vxn}, analyzes them to zero, and if the contents of the loop counter is not equal to zero, changes this parameter to its step value and passes control to operator 15. Then a new calculation will start.

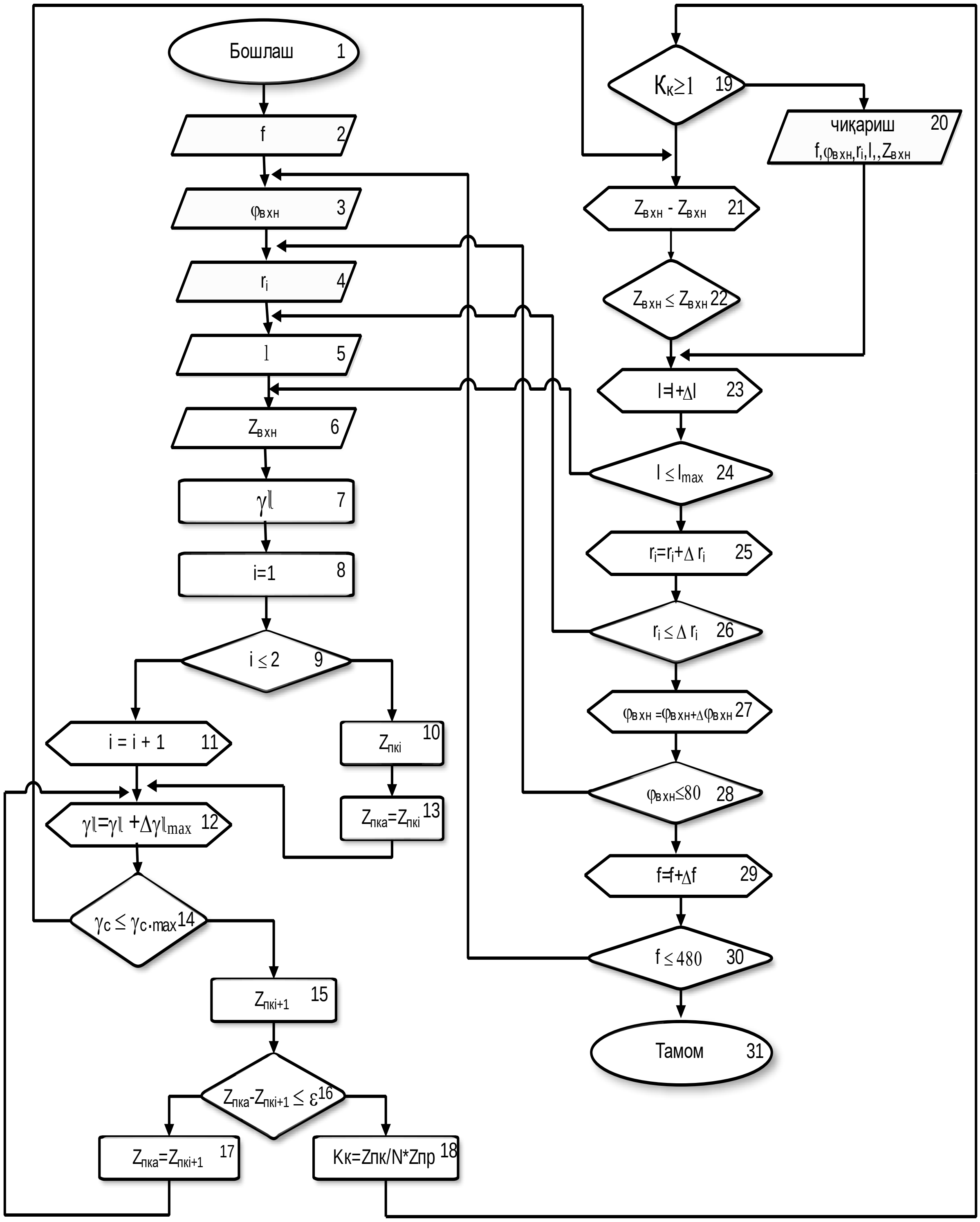


Figure 3.11. Block diagram of the algorithm for determining the optimal parameters of the control sensor from the conditions of normal and shunt operation

Operators 16-24 are a block diagram of options for different lengths. insulation resistance and current frequency of the rail line.

The results of the calculation of the maximum allowable length of the control sensor are shown in Figures 3.12 – 3.13.

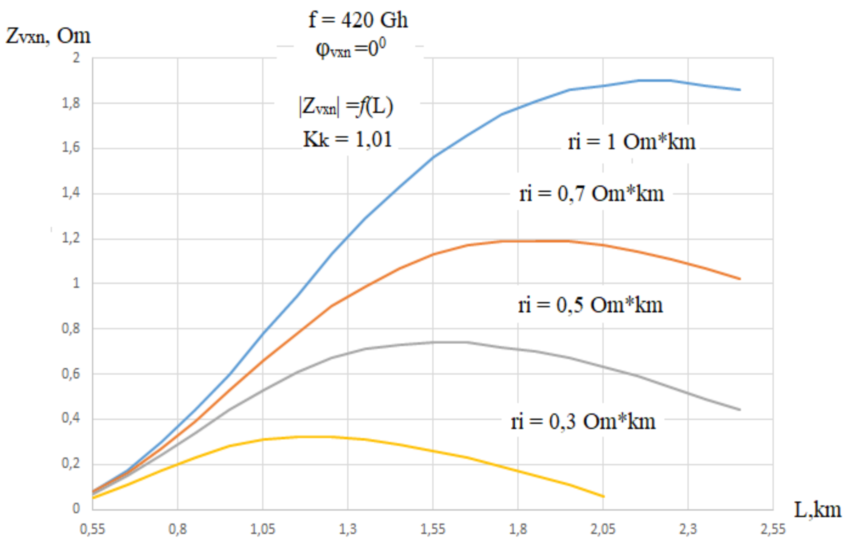


Figure 3.12. Graphs of the input resistance dependence of the control sensor provided that the shunt sensitivity to the chain length at the signal frequency $\phi_{вхн} = 0^0$ and f = 420 gs

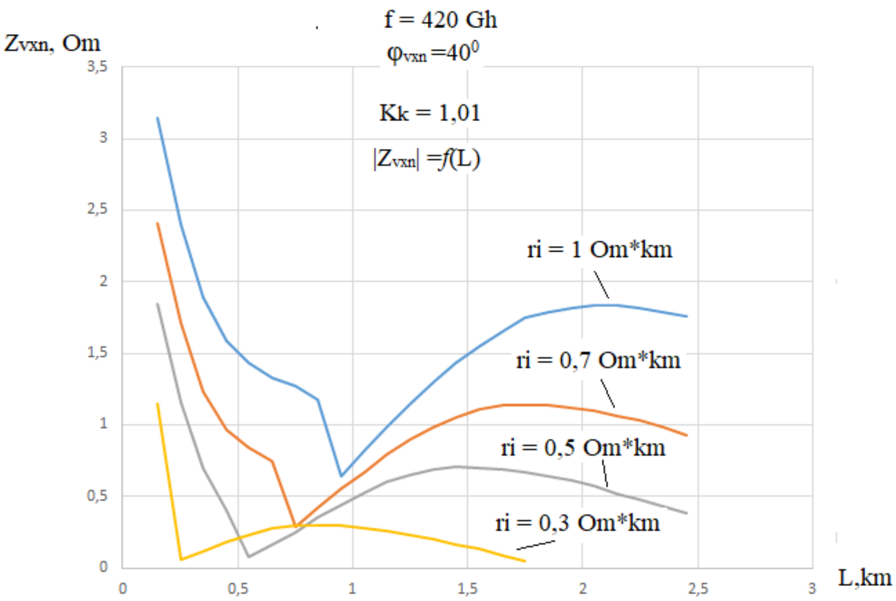


Figure 3.13. Graphs of the control sensor input resistance dependencies provided that the shunt sensitivity to the chain length at the signal frequency $\phi_{вхн} = 40^0$ and f = 420 gs

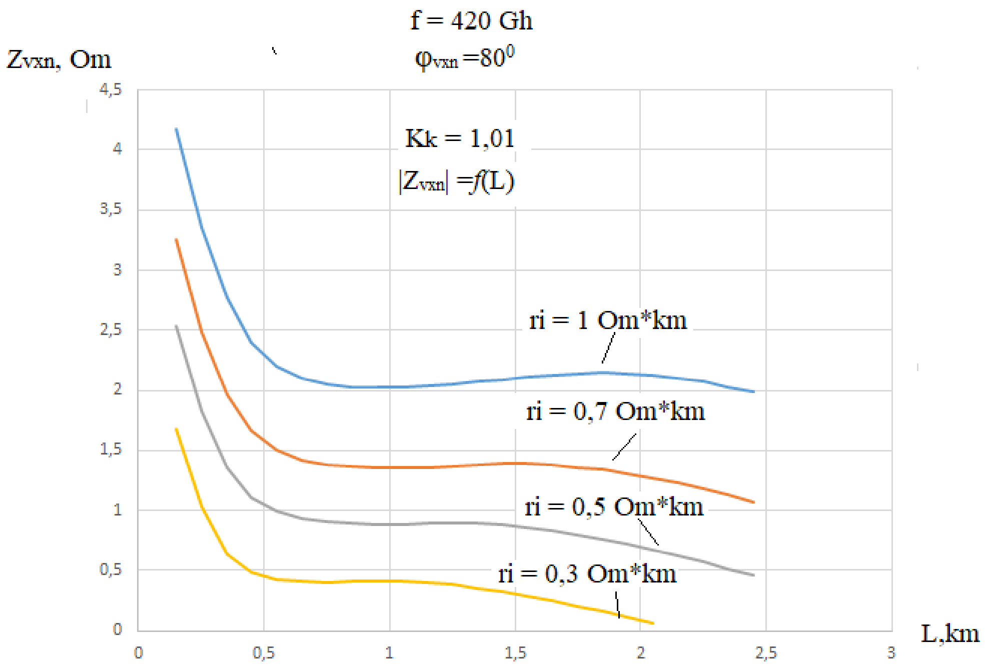


Figure 3.14. Graphs of the control sensor input resistance dependencies provided that the shunt sensitivity to the chain length at the signal frequency $\phi_{вхн} = 80^0$ and f = 420 gs

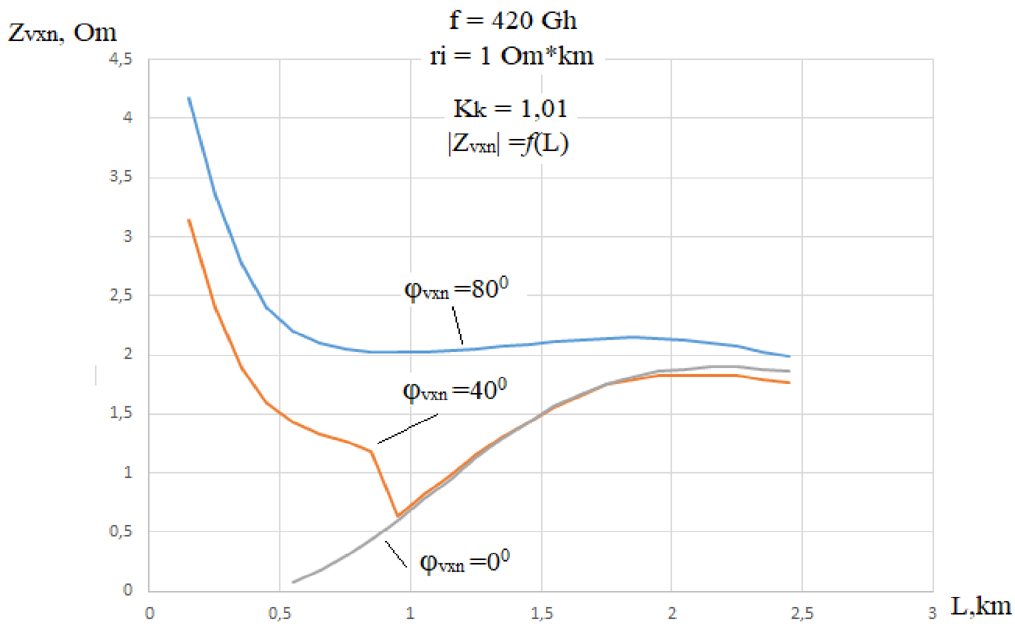


Figure 3.15. Graphs of the input resistance dependence of the control sensor provided that the shunt sensitivity to the chain length at the signal frequency $\phi_{вхн} = 60^0$ and f = 420 gs

The following conclusions can be drawn from the analysis of graphs (3.10 – 3.13):

1. As the length of the rail track increases, the resistance modules at the end of the control sensor increase significantly

2. The length of the rail line depends on the insulation resistance (ballast) of the rail line, the length of the rail line decreases with decreasing insulation resistance;

3. The length of the rail increases with increasing resistance arguments at the ends of the control sensor;

4. The optimal length of the control sensor varies from 2 to 4% of the frequency of the signal current, which does not significantly affect the operating modes of the sensor.

3.6. Mathematical model and algorithm for determining the optimal parameters of the sensor to observe the approach of the train to the intersection in normal and control modes

Control mode is a control mode of breaking one of the tracks, as shown in Figure 3.17, the rail-ballast does not completely interrupt due to the flow of current through the ballast along the rail-rail line.

In general, the rail line is considered in the form of two rails – the earth circuit, in which the mutual induction of M12 and the mutual inductance of $z_м = j2\pi fM_{12}$ are related to the respective individual resistors. Conductivity q_1 and q_2 are the transition permeability between each rail and ground, respectively, to the right and to the left of the rail chain equipment connection points, the permeability q_{12} is directly to the rails in the top layer of ballast and sleeper Describes a part of the current flowing through the grid. z_m is the mutual inductive resistance of the rails.

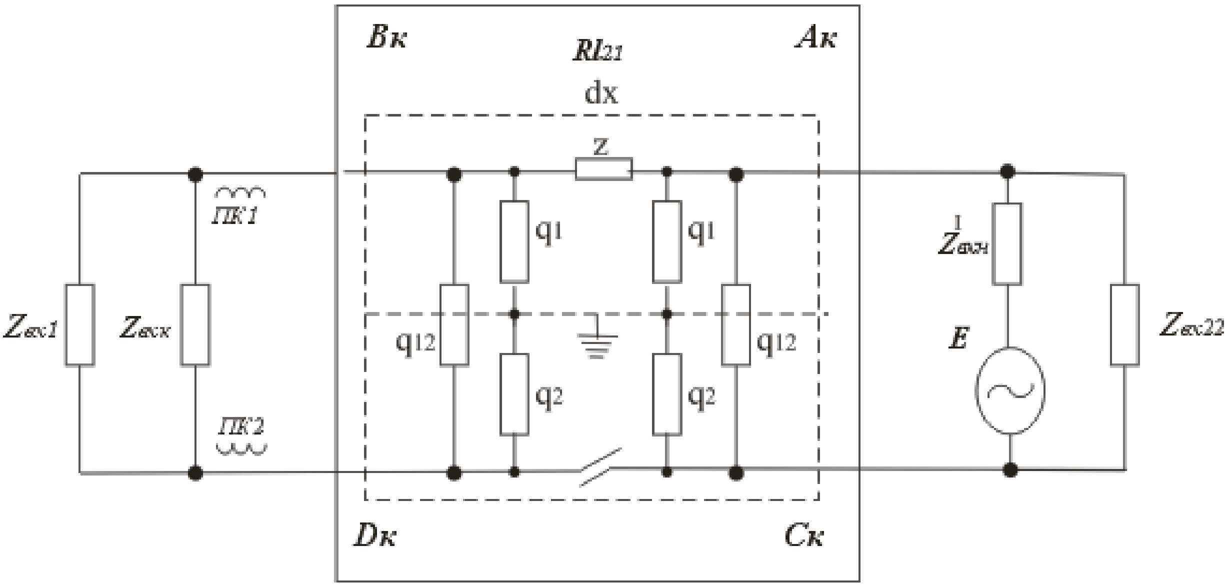


Figure 3.16. Control mode switching scheme

The rails four-pole coefficients for this scheme can be presented in the form of the following equations:

$$A_k = ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21} + E\sqrt{1+2p}(ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21}) + E\sqrt{1+2p}; \quad (3.13)$$

$$B_k = \frac{zl}{\gamma_{21}l_{21}}\left[sh\gamma_{21}l_{21} + E\sqrt{1+2p}(ch\gamma_{21}l_{21} + 1)\right]; \quad (3.14)$$

$$C_k = \frac{2\gamma_{21}l_{21}}{zl}\left[1 + E\sqrt{1+2p}\right]\left[ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21}\right]; \quad (3.15)$$

$$D_k = ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21} + E\sqrt{1+2p}(ch\gamma_{21}l_{21} + sh\gamma_{21}l_{21})E\sqrt{1+2p}. \quad (3.16)$$

The interrupt sensitivity of the rail determines the effect of reducing the current on the receiver in the control mode:

$$K_k = \frac{I_{нн}}{I_{фмакс}}. \quad (3.17)$$

$$I_{нн} = I_{ср} * k_в = \frac{U_{min} * k_в}{Z_{по}}; \quad (3.18)$$

where U_{min} – minimum supply voltage;

K_v – the reliable return coefficient of the receiver;

Z_{po} - transmission resistance of the rail chain during normal mode operation:

$$Z_{po} = A_0 * \frac{vxk * z_{в1}}{Z_{vxk} + z_{в1}} + B_0 + Z_{vxn}^I (C_0 * \frac{Z_{vxk} * z_{v1}}{Z_{vxk} + z_{v1}} + D_0).$$

$$I_{fmaks} = \frac{U_{maks} * k_з}{Z_{pk}}. \quad (3.19)$$

where U_{maks} – maximum supply voltage;

K_v - the reliable return coefficient of the receiver;

Z_{pk} - transmission resistance of the rail chain during control mode operation:

$$Z_{pk} = A_к * \frac{Z_{vxk} * Z_{v1}}{Z_{vxk} + z_{v1}} + B_к + Z_{vxn}^I (C_к * \frac{Z_{vxk} * Z_{v1}}{Z_{vxk} + z_{v1}} + D_к).$$

Substituting Equations (3.18 and 3.19) into Equation (3.17), we obtain:

$$K_k = \frac{\frac{U_{min} * k_в}{Z_{po}}}{\frac{U_{maks} * k_з}{Z_{pk}}} = \frac{U_{min} * k_v * Z_{pk}}{U_{макс} * k_z * Z_{po}}$$

we will replace it

$$\frac{U_{min} * k_v}{U_{maks} * k_z} = \frac{1}{N},$$

where N is the hardware coefficient equal to 1.7, then

$$K_k = \frac{A_к * \frac{Z_{vxk} * Z_{v1}}{Z_{vxk} + z_{v1}} + B_к + Z_{vxn}^I (C_к * \frac{Z_{vxk} * Z_{v1}}{Z_{vxk} + z_{v1}} + D_к)}{N * A_0 * \frac{Z_{vxk} * Z_{v1}}{Z_{vxk} + z_{v1}} + B_0 + Z_{vxn}^I (C_0 * \frac{Z_{vxk} * Z_{v1}}{Z_{vxk} + z_{v1}} + D_0)} \quad (3.20)$$

This equation is the basis for determining the optimal parameters of the rail chain in control mode.

Based on the above, an algorithm was developed (Figure 3.11), a program was developed, and the research was conducted on a computer. In the study, the minimum value of the conductivity Z_{pk} is determined first, and then the coefficient K_k is determined. The input resistance at the ends is carried out in two stages, provided that the optimal values of the length of the control sensor are searched and normal operating modes are ensured: in the first stage the minimum value of Z_{pokp}

transmission resistance is determined, in the second stage $K_{kп}$ if it has a value equal to or greater than that, then these ends will have the desired optimal modulus of resistance.

To determine the optimal modulus of resistance, the computer enters the following initial data: frequency *f*, module Z_{vxn} and the resistance argument, all possible values of r_i, γl and l.

In the process of searching for the optimal value, the operators form 1 ÷ 6 contacts and send them to the rotary counters to organize the finding of the minimum value of the function $Z_{pokpmin} = f(|\gamma l|)$ and the optimal value of the resistance modulus for different options.

After determining the minimum value of the function $Z_{pokpmin} = f(|\gamma l|)$, control is passed to operators 16 and 12, who calculate the sensitivity criterion for the broken rail trace and compare this criterion to observe the broken rail trace $K_{kp} \geq 1$.

If the sensitivity criterion is less than one, then control is transferred to 13 ÷ 15 operators. which changes the contents of the loop counter one by one with the parameter Z_{vxn} changes the parameter to Z_{vxn} step value and restores the γl value.

If the sensitivity criterion is equal to or greater than one, then the control is passed to 17 operators, which prints the Z_{vxnopt} values and passes control with a block diagram of 18 ÷ 30 parameters [85]. Each of them changes the content of the cycle counter one by one for a certain parameter, analyzes it to zero, and if the content of the loop counter is not equal to zero, it changes this parameter with the value of its step and 'transmits control to restore data. If the content of the counters is zero, then control is passed on to the operators that make up the next parameter of the cycle.

After completing all combinations, the computer prints the end mark and stops. Calculation results Figure 3.15 – 3.18.

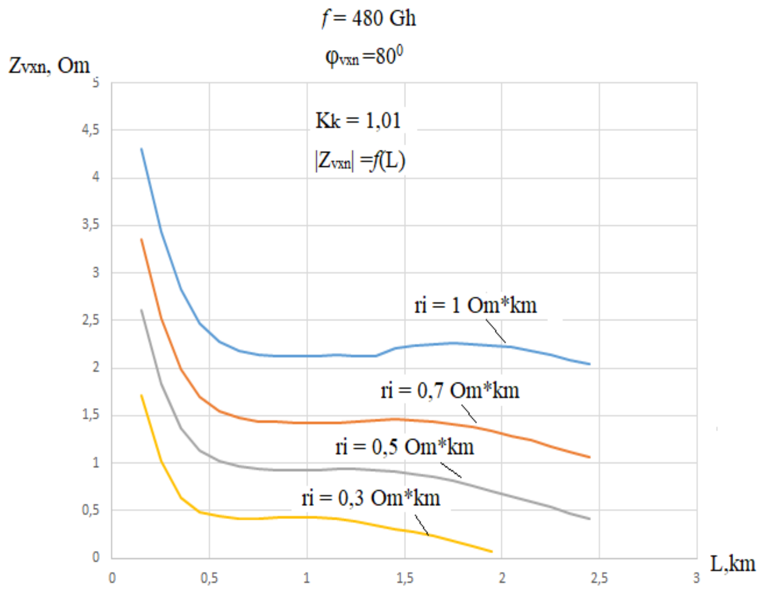


Figure 3.18. Connection graphs of the input resistance of the control sensor, provided that the refractive sensitivity of the rail track of the chain length at the signal frequencies f = 480 gs and $\phi_{вхн} = 60^0$

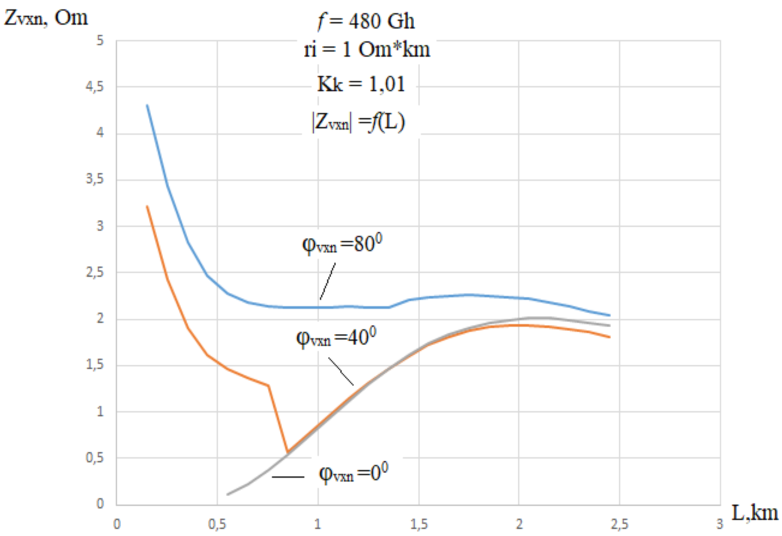


Figure 3.19. Connection graphs of the input resistance of the control sensor, provided that the refractive sensitivity of the rail track of the chain length at the signal frequencies f = 420 gs and $\phi_{вхн} = 60^0$

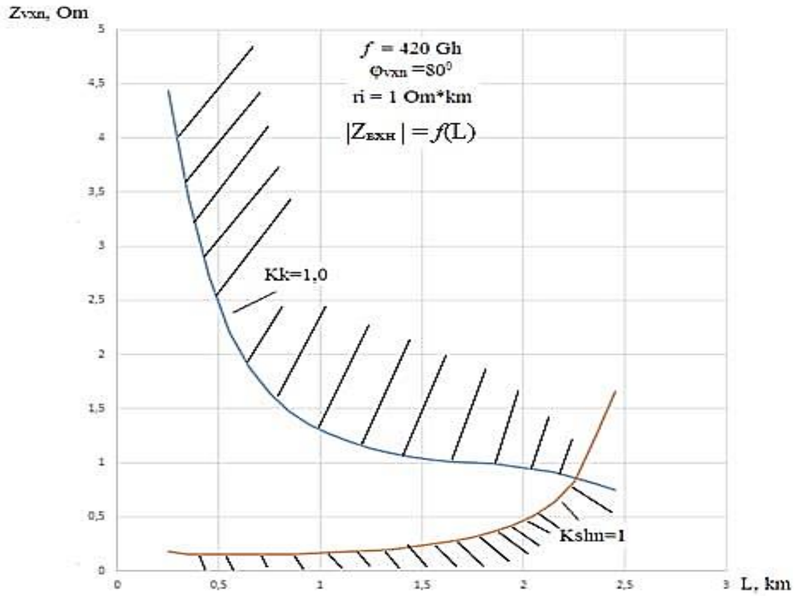


Figure 3.20. Dependence graphs of the input resistance of the control sensor, provided that the refractive sensitivity of the rail track of the chain length at the signal frequencies f = 420 gs and $\phi_{вхн} = 80^0$

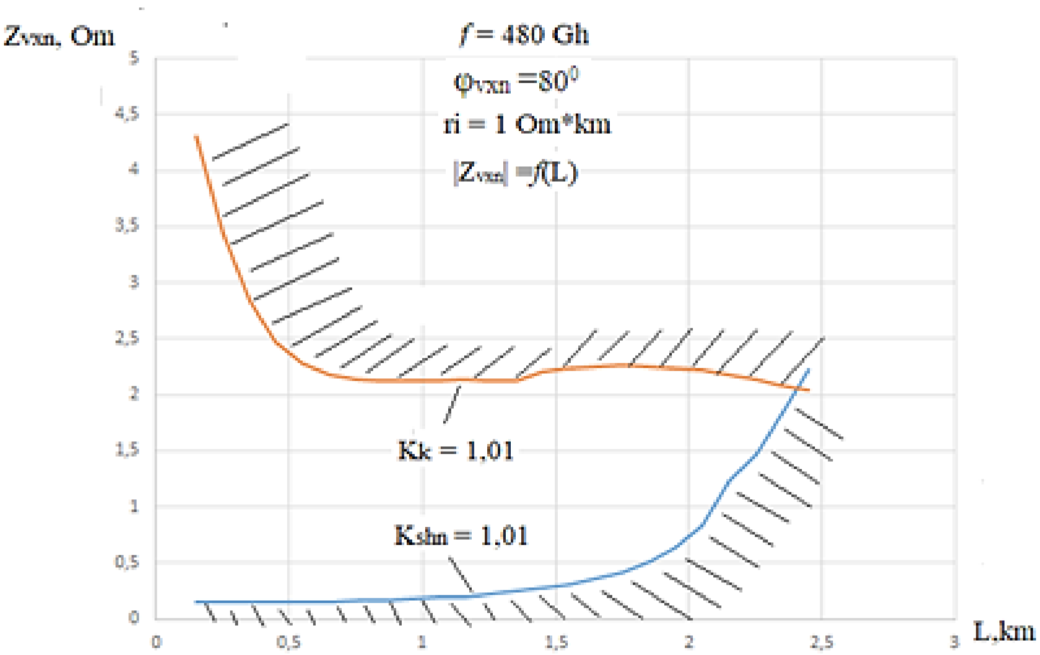


Figure 3.21. Connection graphs of the input resistance of the control sensor, provided that the fracture sensitivity of the rail track of the chain length at the signal frequencies f = 480 gs and $\phi_{вхн} = 60^0$

The following conclusions can be drawn from the analysis of graphs (3.15 – 3.18):

1. As the length of the rail track increases, the resistance modules at the control sensor ends decrease;

2. As the insulation resistance increases, the resistance modules at the ends of the control sensor increase and the length of the rail line also increases;

3. The length of the rail line also depends on the resistance arguments at the end of the control sensor;

Based on the above findings, a generalized conclusion can be made:

1. In order to control the operation of the controlled rail line (shunt mode), it is necessary to increase the modules and arguments of the resistances at the ends of the control sensor to increase the length of the rail;

2. The resistance modules at the ends of the control sensor should be reduced, provided that the refraction (control mode) of the rail ring is controlled;

3. From the above, it can be seen that the optimal parameters of the control sensor can be determined at the intersection of the shunt curves and the control sensor control modes.

3.7. Development of a program and algorithm for determining the optimal location of control sensors approaching a railway crossing

Railroad crossings are being built at the same level intersections of railways and highways. To ensure the safety of trains and vehicles, the crossings are equipped with protective devices to create conditions for the unimpeded movement of trains and to prevent the train from colliding with oncoming vehicles. Depending on the intensity of traffic at the crossings, barriers are in the form of automatic stoplight signaling, automatic crossing signal with automatic barriers, automatic or non-automatic warning devices (mechanically manual or electrically controlled) used.

The formula of the approach to the railway crossing, the software developed on the basis of the algorithm, further increases the reliability of this object.

The rapid growth of the fleet of cars belonging to the citizens of Uzbekistan is accompanied by an increase in the number of road accidents, on the one hand, and an increase in traffic on the other. However, in the last 5-8 years, delays in road crossings (especially in the suburbs and suburbs, at the intersections of highways and railways) have increased sharply.

Due to the high level of motor traffic in Uzbekistan and the increase in the number of vehicles, the problem of the capacity of highways has intensified. When there is a level crossing of highways with railway lines, the capacity is reduced by 1, 5-2, which leads to long delays in road transport at railway crossings.

According to the methodology for the design of automatic warning devices at railway crossings, the train must give a warning message when approaching a railway crossing, if the car entered the railway crossing when the signal was activated, no l should end crossing and provide complete safety.

The area of approach to a railway crossing is calculated according to the following formula [22].

$$L_{warning} = 0{,}28 * V_{\max} * t_4, (м), \quad (3.1)$$

Where 0.28 is the conversion coefficient of the speedometer from km/s to m/s;

- maximum speed of the train on the section;

- The required notification time is calculated according to the following formula:

$$t_4 = t_1 + t_2 + t_3, (c), \quad (3.2)$$

Here is the alarm activation time;

- additional guaranteed time (10 s);

- the time the vehicle passes through the railway crossing is calculated according to the following formula:

$$t_1 = \frac{l_n + l_{mp} + l_o}{V_м}, (c), \quad (3.3)$$

Here is the length of the railway crossing (20 m);

- maximum length of the car (24 m);

- distance from the parking lot to the traffic light (5 m);
- Velocity of the vehicle at the railway crossing (1.4 m / s) [22].

Figure 3.22 shows a block diagram for calculating the length of the approach section of a road and rail intersection, depending on the speed of the trains.

Also, the design calculation software of the guarded railway crossing will facilitate its construction. The software is designed to calculate the length of the approach section of a road and rail intersection, depending on the speed of the trains in rail transport [81].

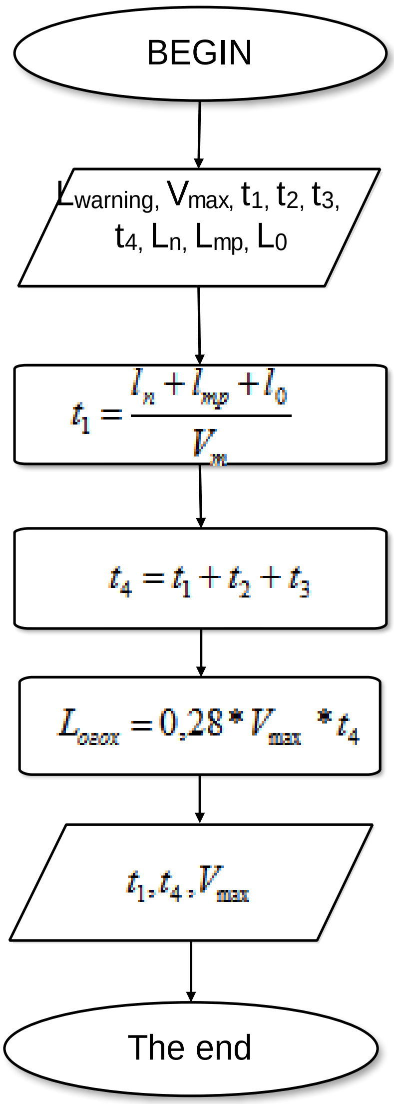


Figure 3.22. Block diagram for calculating the length of the approach section of the intersection of highways and railways, depending on the speed of trains

The program includes:

- time spent by the vehicle crossing the railway crossing;

- calculate the length of the approach section at the time of the warning message at the railway crossing;

Depending on the speed of the trains, the following steps are used to calculate the length of the section near the crossing: 1) Data to find the length of the section approaching the level crossing: maximum speed of the train on the section; 2) To enter the required message, enter the data: time to receive the signal; additional guaranteed time; 3) Enter data to calculate the time of the passing vehicle: the length of the level crossing; maximum vehicle length; the distance from the parking lot to the intersection stoplight; the speed of the car at the intersection.

Working with software increases speed and visualization of results, performance and reliability. Also, one of the most interesting and promising tasks for intelligent transport systems is related to the problem of congestion. Overloading is a pressing transport problem, as it reduces infrastructure efficiency and increases travel time, air pollution, and fuel consumption [15]. V2V (vehicle-to-vehicle) is a car technology designed to allow cars to "talk" to each other. The technology is expected to increase the safety and efficiency of railway crossings [15].

According to the developed program, the approach to the intersection was calculated for a train speed with a section length V = 250 km / h, the length of which was 3080 meters.

The AKS system provides for the closure of the intersection for a period of time to prevent vehicles from coming to a permanent stop at the intersection. Corresponds to the distance traveled by trains from the control sensors to the L_nd intersection.

$$t_{kbuq} = t_{xv} - t_{kyov} - t_{tkv} \tag{3.4}$$

where t_{xv} train travel time from control sensors to the intersection;

t_{kyov} – closing time of the intersection device;

t_{tkv} – waiting time for vehicles at the intersection.

Time is t_{xv} – the transition time of the train from the control sensors to the intersection is determined by the following formula:

$$t_{xv} = \frac{L_{nd}}{0{,}28 * V_{max}} \tag{3.5}$$

where L_{nd} is the distance from the intersection where the speed control sensors are installed.

0.28 km / h conversion rate;

V_{max} is the maximum speed of the train.

The waiting time for cars after the intersection is closed is t_{akv}:

$$t_{akv} = t_{xv} - t_{kyov}. \tag{3.6}$$

If we take this time as the standard for the remaining speeds of trains, then the closing time of the intersection is determined by the following formula:

$$t_{close} = t_{xv} - t_{etolon}. \tag{3.7}$$

According to the calculations made in Chapter 3.2, it was found that the length of the tonal rail chain with current receivers was 2,200 meters, taking into account the provision of all operating modes of the rail chain.

Since the length of the approach section for maximum speed is 3080 meters, it is necessary to use two rail chains with speed control sensors installed at the entrance of the first rail chain at a distance of 4400 meters from the intersection to ensure this length. Figure 3.23.

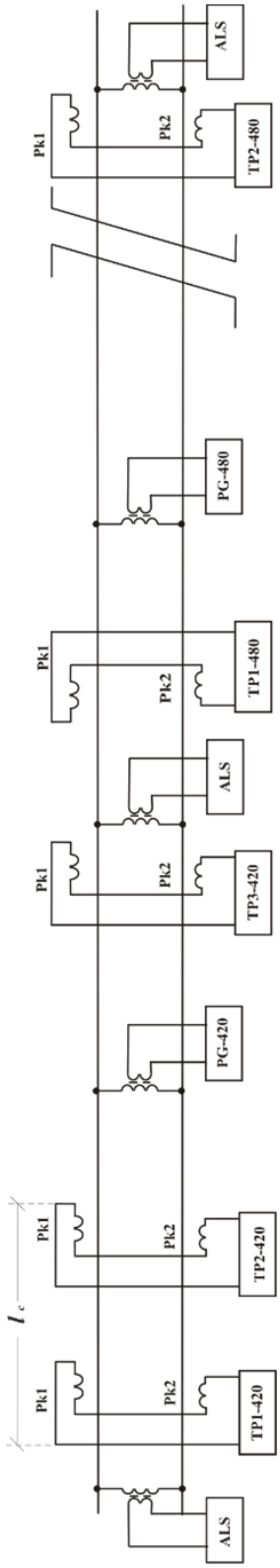


Figure 3.23. Schematic of a control sensor with a current receiver

Conclusions

1. A program and algorithm for determining the optimal location of control sensors approaching a railway crossing have been developed and their advantages have been studied.

2. The shortcomings of the automatic signal control circuit for two-way automatic blocking in alternating current were studied, and a control method for crossing the train with rail chains using insulating joints was developed.

3. The microprocessor-based automated intersection signaling system was analyzed and a control method was developed for crossing the train crossing with rail chains using uninsulated joints.

4. A mathematical model of the sensor was developed and graphs were created to control the approach of the train to the railway crossing in the control mode.

CHAPTER IV.
DEVELOPMENT OF SOFTWARE AND TECHNICAL SOLUTIONS OF RAILWAY CROSS CONTROL SENSORS

This chapter describes the circuit diagrams of an intersection signaling microprocessor and explains that it has a system based on a new technology model. The cost of the new protection device is also calculated. In the end, it is based on a system with an innovative structure around the world.

4.1. Development of microprocessor control device circuits for railway crossing signaling

At present, the Uzbek railways use relay-contact automatic cross-signaling devices, which almost cease to meet the modern requirements to ensure the safety of spiritually and technically obsolete vehicles and trains.

We offer state-of-the-art microprocessor-based control and monitoring systems for automated crossing signaling devices with auto-barriers that ensure the safety of trains and vehicles on these sections.

It is recommended to use a microcontroller from the well-known company Intel MCS-51, which is best suited for this purpose, to control and monitor the operation of automated intersection signaling with automatic barriers. The unique feature of this microcontroller is that it has four input and output ports, enough internal and expandable external memory to manage the intersection of devices and control programs.

The scheme of the developed microprocessor intersection system is shown in Figures 4.1 and 4.2.

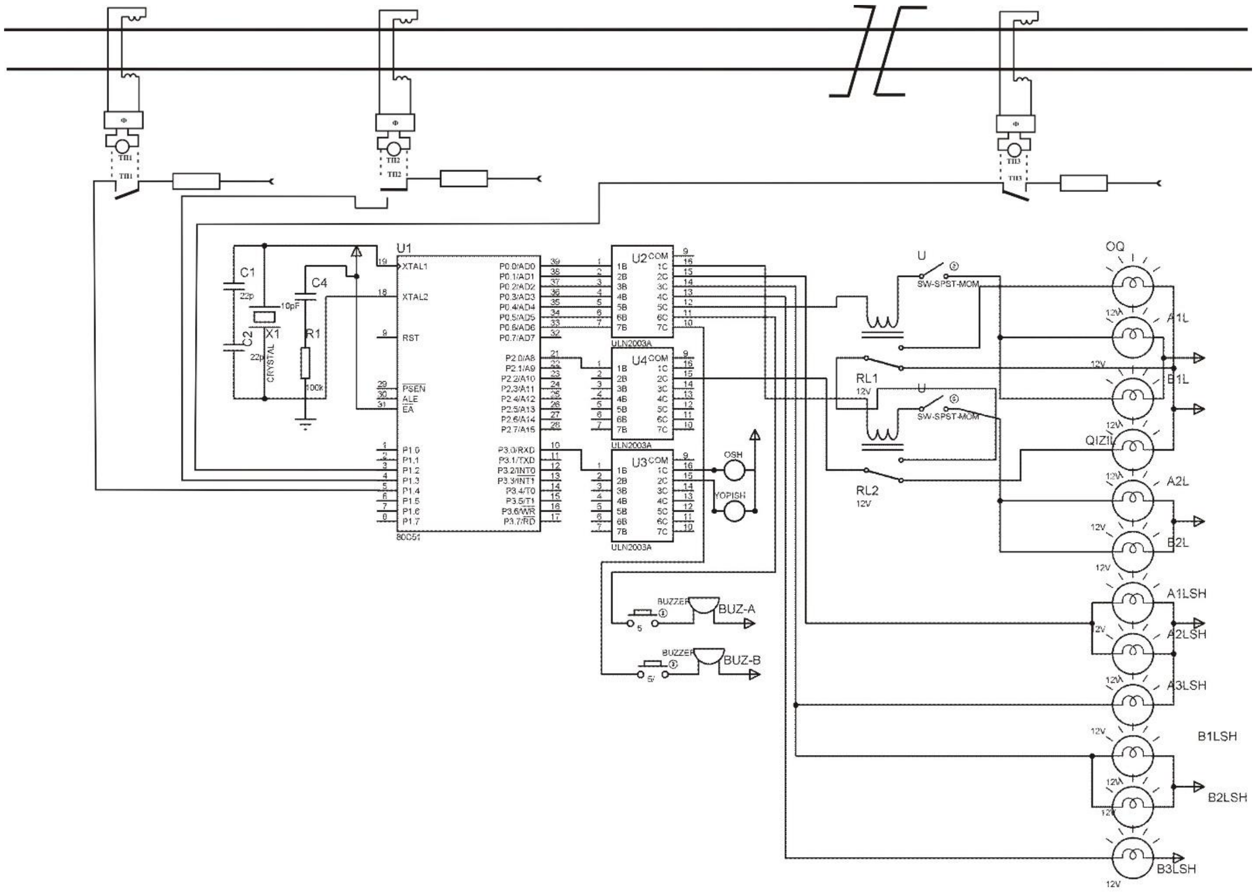


Figure 4.1. Microprocessor intersection signaling with boom gate

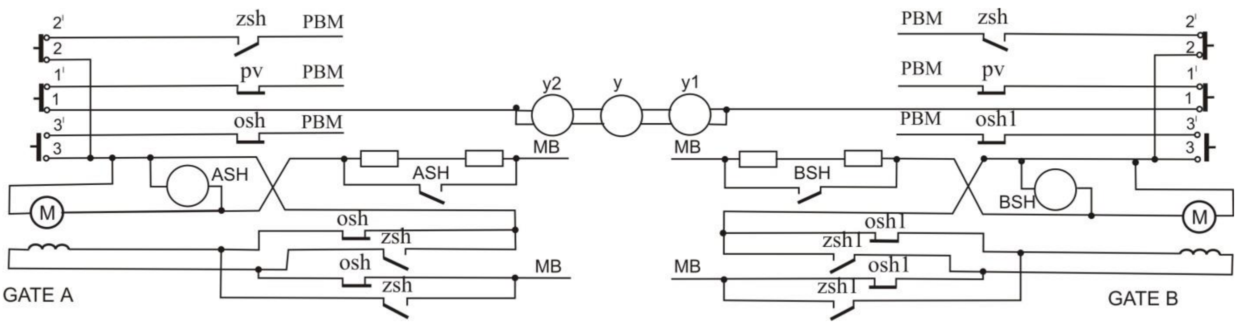


Figure 4.2. Railroad Gate management scheme

The automatic control of the barrier is done as follows:

If there is no train on the approaching section, the intersection is open, the OSH relay is on, the barrier is raised, and the automatic switches 3-3I (Figure 4.2) of the armature chain and the electric motor are off [22].

The open position of the barrier is controlled by the power supply position of relays U and U1, which are switched on by the closed contacts 1-1I of the circuit breakers. The rear contacts of the relay turn off the traffic lights and intersection lights.

When the train enters the approach section, the TP1 sensor is activated via the contact of this sensor, a logical “1” signal is sent to the microcontroller. According to the program, the microcontroller starts a timer to determine the speed of the train approaching the intersection. When the train head enters the second TP2 sensor, a signal is sent to the microcontroller to stop the timer. Then, according to the program, the speed of the train approaching the intersection is calculated, and depending on the speed of the train, the closing time of the intersection is determined and the timer is turned on, which determines the closing time of the crossing. When the timer expires, the lights and bells light up. The calls will continue until the barriers are completely closed and the 5-5I contacts of the cars are opened, the intersection stoplights and the lights on the barriers are turned on. The 1L and 2L intersection lights illuminate with a flashing red light, which signals a vehicle in front of a closed intersection to stop [89]. The 1LSh and 2LSh lamps on the automatic barrier grille also illuminate with a flashing red light, while the 3LSh lamp at the end of the barrier grille illuminates with a continuous light.

After the intersection lights are on, the roadblocks will be closed with a delay. It is important to make sure that the car entering the railway crossing is completely closed before the roadblock is closed. At this time, the delay timer is activated. When the timer is over, the relay is switched on to close the ZSh barriers and the relay OSh is switched off to open the barriers.

The ZSh relay with front contacts lifts the armature chain and the motor of the auto-slagbaum electric motor. The direct current passes through the polarized drive shaft, so the electric motor turns towards closing the overhead barrier. The barrier fence is placed horizontally and the intersection is closed. At the same time, the 2-2I (AP) contacts turn on and the electric motor turns off, the 5-5I (AP) contacts turn on and the calls turn off. The lights of the intersection traffic lights and auto barriers continue to flicker.

The intersection will remain closed until the train passes completely. When the train is fully moving, the TP3 sensor is activated, the data is transferred to the microcontroller, which turns off the ZSh relay and turns on the OSH relay.

The anchor chain is closed by the front contacts of the OS relay, and the windshield of the electric motor is raised to open the intersection. When the barrier is closed, the current flows in this direction through the armature. The desert is in the opposite direction when it rises. The armature of the electric motor rotates in the opposite direction, the barrier rises. When the barrier grille is vertical, the 3-3I (AP) electric motor, as well as the intersection stoplights and the lights on the auto barrier grille, turn off. The intersection returns to its original state.

4.2. Development of algorithms and programs for the management of railway crossing signals

An algorithm based on the above has been developed for the control and management of intersecting auto-signals and signaling devices.

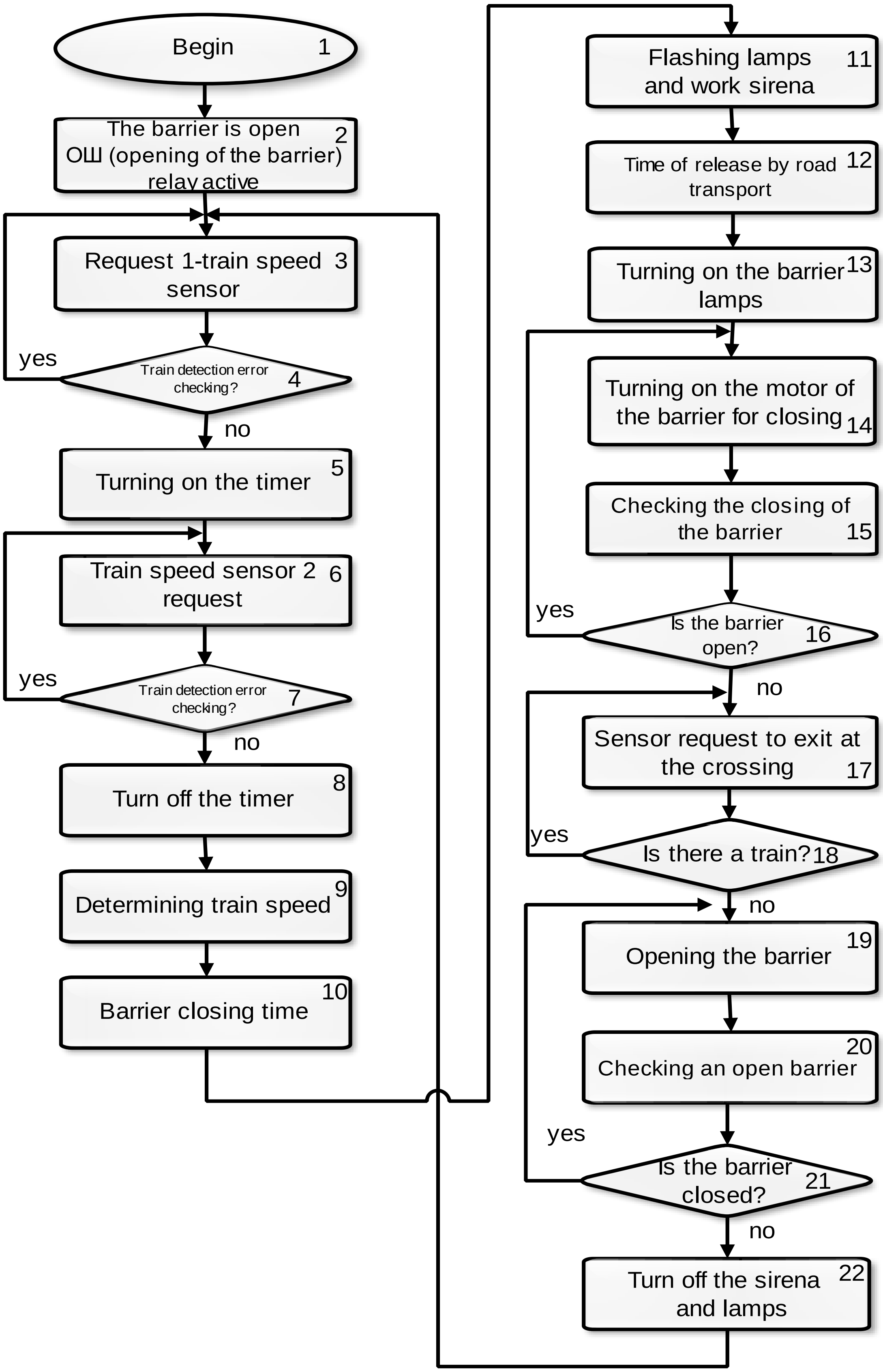


Figure 4.3. Sensing block diagram of a sensor-based railway crossing

Intersection signaling and barriers are controlled by the following algorithm – block diagram in Figure 4.3.

In the first case, the intersection is open, block barrier relay OSH (barrier opening relay) is supported, block 2, barrier bars are raised, intersection traffic lights are off.

A signal is sent to the microcontroller from the current receiver TP1 (block 3) via the communication line, which is checked at the entrance to the approaching section of block 4, if the train does not enter the approaching section, then this receiver is constantly checked. When the train enters the approach section, the TP1 current receiver is activated. The comparison block detects that the train has entered the approach section and transfers control to block 5, the train switch turns on the timer to determine the time of transition from the TP1 current receiver to the TP2 current receiver (blocks 6 and 7). After the main part of the train passes behind the current receiver TP2, control is transferred to block 8, where the speed of the train approaching the intersection is determined. Then, according to the determined speed, the control is transferred to the 10th block, where the time of closing the intersection is determined. Control is then transferred to Unit 11, where a signal is generated to turn on the intersection stoplights and intersection signaling. A timer is switched on (block 12) to determine the time of departure of vehicles from the intersection, and a relay is switched on to close the ZSh boom gate. The ZSh relay rises, turns on the auto-barrier motors and controls the closing of the bars (block 13), (block 14 i15) and the closing of the barrier. The barriers closed the intersection and the system monitored the train's exit from the intersection (blocks 16.17). When the train leaves the intersection, a signal is sent to the OSH barrier opening relay (block 18). The barrier bars have been raised, and the lifting control of the bars is controlled by blocks 19 and 20. After lifting the barrier bars, the signal lights go out (block 22) and the system returns to its original state. Control is transferred to block 2. Based on the developed algorithm, a program for managing and controlling the operation of intersection signaling with boom gate was developed, Annex 5.

4.3. Criteria for calculating the cost of maintaining the Bollard barrier

With heavy traffic, as well as at railway crossings with high speeds of passenger trains, special devices can be used to prevent the unauthorized entry of vehicles into the crossings. When repairing roads, structures and facilities, the roadway shall be installed at least 1 meter away from the main barriers in the direction of the road and the carriageway shall not be less than the others. spare horizontal-rotating arm barriers should be used to block the case. These barriers must have devices to secure them in the open and closed positions and to hang the signal lamp. But often some vehicles are delayed and disrupt traffic. In this case, a safer transition device is required. Bollard devices are effective herey.

The economic benefit of using a bollard barrier device is that it helps to ensure a high level of safety of crossings, creating a barrier for dangerous vehicles approaching them.

The cost of purchasing and maintaining a barrier device consists of capital investment and operating costs, which are determined by formula [5].

$$P=E+K*En. \quad (4.1)$$

here E-operating costs, thousand rubles;

K-capital income, thousand soums;

En -standard efficiency coefficient, En = 0.12.

Construction and installation work is required to install the barriers. This is the responsibility of device vendors and installers. Each barrier is estimated at 1,500,000 soums, and six barriers are required to block one crossing. The dam, oil pump station, electrical control cabinet, high-pressure hoses and remote controls also cost about 1,500,000 sums.

Capital investment will be K = 155,000,000 soums.

The operating costs required to maintain the barrier are the sum of the cost of electricity and depreciation.

Operating costs are determined by the following formula:

$$E=Eel + A. \qquad (4.2)$$

where Eel electricity cost, thousand soums;

A-depreciation allowance, thousand soums.

Depreciation percentage is defined as follows [36]

$$A=1/PSI\cdot 100\%, \qquad (4.3)$$

Here PSI is the lifespan of the facility in use, years.

$$A=1/20\cdot 100\%=5\%$$

Thus, the amount of depreciation is 5% of the value of the barrier device:

$$A = 155\ 000\ 000 \cdot 5\% = 7\ 750\ 000 \text{ sum}$$

The cost of electricity for the operation of the defrosting device per month is given in Table 17.

Table 17

Electricity consumption

Electricity consumption, kW · s	Price for 1 kW / h, UZS.	Consumption, sum
500	228,60	114300

The operating costs associated with the operation of the defrosting unit are as follows:

Land = 114 300 + 7 750 000 = 7 864 300 sums.

It turns out that the total cost of purchasing and maintaining a barrier device is:

P = 7 864 300 + 155 000 000 * 0.12 = 26 464 300 soums.

When designing a new device, it is necessary to calculate the design costs, which are directly related to the duration of its implementation. The software product therefore addresses issues related to cost estimation during design, as well as the calculation of labor intensity, as well as the calculation of costs for the implementation and operation of a new bollard device.

The issue of cost-effectiveness of the work carried out in the implementation of the information project for any enterprise is of paramount importance. In short, should financial, material and other types of resources be invested in the project? In addition to Heren, it does not matter how the project is implemented: either it is an information system developed at home (optionally, an information system developed by a third-party manufacturer for a specific customer) or a system provided as an opportunity to solve specific business problems.

4.4. Application and analysis of Vehicle to infrastructure (V2I) and Vehicle to Everything (V2X) technologies at railway crossings

Vehicle to Everything (V2X) connection. The Car-to-Everything (A2X) connection is the transmission of information from the car to any person affected by the car, and vice versa.

Vehicles involving buses, trams, and private cars are equipped with automotive communication devices (ACS) and V2X software to communicate with road infrastructure such as vehicles, pedestrian smartphones, and traffic signals and pedestrian crossings.

The system aims to improve safety, reduce congestion and emit gas by focusing on six key traffic issues.

- Incorrect entrances - safety measures are addressed by warning about improper entrances at intersections.

- Pedestrian safety - V2X solutions are used to reduce accidents on pedestrians and vehicles when the driver is not paying enough attention or when pedestrians choose short routes.

- Improvement of traffic - the interaction of transport modes is optimized with V2X solutions to reduce congestion and pedestrian accidents [25].

- Morning peak hour shift - Vehicles equipped with V2X technology help drivers make safe and smooth shifts during rush hour hours.

- Tram conflicts - tram operators, bus drivers, motorists and pedestrians are informed to reduce collisions and incidents with pedestrians near tram stops.

- Optimization of bus speed transit signals, travel times and safety - Delays due to congestion near bus stops will be addressed with improved road priorities to optimize traffic flow.

Railroad Crossing and Connected Vehicle Technology.

- A system has been developed to warn drivers of the presence of a train approaching a railway crossing or coming to an intersection without a barrier.

- A system that uses a wireless connection to deliver in-vehicle warning messages for vehicles equipped with the system.

Connected vehicle communication protocols and Grade-Crossing technology:

1. Vehicle Infrastructure (V2I) technology offers the ability for two-way data exchange between vehicles and road infrastructure;

2. It is aimed at coordinating the group movements of vehicles based on the data collected on transport and road conditions.

- includes the speed and acceleration of congested vehicles;

- contains information on the condition of the railway crossing;

- oversees infrastructure to improve road safety;

- includes the transmission of messages through road displays or the adjustment of traffic signals;

- warns motorists when access to intersections and railway crossings is dangerous;

Development of autonomous vehicle technology:

- The development of autonomous vehicles in a real operational test environment is limited by some of the operational scenarios that occur in road operations, including railway crossings.

- The further development of autonomous car platforms should consider all operational scenarios, in particular, crossings.

- The technology of connected vehicles available at the crossings of autonomous vehicles provides the interaction of the level of safe and efficient crossing, based on the functional capabilities of autonomous vehicles. Involving original equipment manufacturers and Level 1 suppliers will help determine the status of autonomous vehicle technology and the readiness of these systems, as they are associated with safe navigation when crossing intersections.

In the future, in order to improve and improve the railway crossing, it is necessary to introduce a system of transition from vehicles to infrastructure and from vehicles to vehicles. V2I applications V2V security applications address emergency scenarios that V2V applications cannot solve, and more efficient solutions to some emergency scenarios when there is a low level of access to light vehicles equipped with DSRC (Dedicated short-range communication) fills with. The following is a list of V2I security software that has been developed but not yet developed: Rail Crossing Violation Warning: This technology connects Remote System Explorer (RSE-Remote System Explorer) to drivers at controlled railway crossings assists with available train detection equipment and warns motorists when it is dangerous to cross a railroad.

One of the most interesting and promising tasks for intelligent transport systems (ITS) is related to the problem of congestion. Overloading is a pressing transportation problem, as it reduces infrastructure efficiency and increases travel time, air pollution and fuel consumption.

V2V (car for car) is a car technology designed to allow cars to "talk" to each other. Over the years, important research and projects have been carried out in this area using Vehicular Ad Hoc Networks (VANET – Vehicular Ad Hoc Networks) for a wide range of security navigation and law enforcement applications.

Conclusions

1. Schematic algorithm and model of microprocessor control device of cross-signaling has been developed.

2. An improved block diagram of the intersection was studied, train speed sensors were introduced, and delays for vehicles at the intersection were reduced.

3. The operating program of the autoshlpgbaum in the microcontroller was developed and compared, as well as the control scheme was updated.

4. Developed software to calculate the cost of installation and operation of the Bollard barrier.

5. The safety devices installed at modern intersections were analyzed. Suggestions were made for adaptation to the current situation, as well as the use of autonomous vehicle technology.

CONCLUSION

Theoretical and practical research on innovative devices and safety analysis of railway crossings, principles of calculation of vehicle delays, research models and algorithms have been developed, as well as the development of efficient sensors and solving the problem of the system at old railway crossings. calculations were performed.

As a result, the following key results were achieved:

1. The principles of the indicators of the causes of delays at railway crossings have been developed.

2. Correlation analysis has developed a mathematical model for the study of parametric graph models and simulation results that provide research and design.

3. A sensor model and a graph model and a research algorithm have been developed to control trains at intersections.

4. The general scheme of replacement of the wireless chain is created and formulas of the analytical result are developed.

5. The characteristics of determining the optimal parameters of the control sensor and the conditions for ensuring normal and shunt operating modes are studied.

6. The characteristics of determining the optimal parameters of the control sensor and the conditions for ensuring normal and control operating modes are studied.

7. In determining the optimal closing time of level crossing devices, a microprocessor control system was developed to control the speed of the train approaching level crossing.

8. A program has been developed to control and monitor the speed of trains approaching the intersection.

9. The results of the dissertation allowed to obtain an economic benefit of 145.5 million soums for each intersection.

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ABBREVIATION

STsB – signaling, centralization, blocking;

UPN – section train attendant (yzel);

SN – station attendant;

V2V – from vehicle to vehicle;

V2I – from vehicle to infrastructure;

V2X – car and everything;

DSRC – Private Short Distance Communication;

ITS – Intelligent transport systems;

VANET – Special networks of vehicles;

TP – current receiver;

MP-AKS — Microprocessor Automated Intersection Alarm;

YaAB – semi-automatic blocking;

AB – automatic blocking;

PS1P – (K1HP) Intersection calculation point

RSh MP-AKS – Relay cabinet-microprocessor automatic crossover alarm

OH – bullet counter

YD – traffic sensor

PSO – polgp built - in signal converter

KHP is the point of intersection calculation

HTO is a computational-analytical measure

NU – control extension

TR – single relay

STCh is an artificial reversible line relay

YOR – turn on the relay

JR – double relay

NUA – control transmission exchange

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