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THE THEORY AND PRACTICE OF IMPROVING ROAD TRAFFIC SAFETY AT ACCIDENT SITES THROUGH METHODS OF ROAD TRAFFIC ORGANIZATION

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In article it is resulted results of practical application of is developed methodology on an example of a concrete site to the main street in Minsk. Thus, it is possible to state that the developed methodology of increasing the traffic safety in the accident sites allows to carry out the total complex of the problems on the choice of the optimal decision directed to the improvement of road traffic quality, as a cumulative attribute (taking into account equation of crash, ecological and economic losses).

Keywords: *losses in road traffic, methodology of accident forecasting, accident losses, forecasting methods*

1. Problem Solving

One of the main reasons for the high accident rate in cities is the absence of an appropriate methodology for improving traffic safety at urban accident sites. About 50 % of all accidents in Belarus occur in these places. It is possible and necessary to create a methodology that allows all basic threats to road traffic safety to be considered equally. To realize this it is necessary to create a scientific and methodical system for increasing safety at urban accident sites. In the context of such a methodology it is necessary to develop a high-precision method for forecasting accidents involving conflict objects which allows the accident forecast to be accessed by the decision-making section dealing with road traffic organization. It is also necessary to work out an accident analysis technique for urban accident sites, a technique for defining the calculated social and economic costs of accident, calculation techniques for accident rate forecasting and accident losses for typical objects and techniques for calculating the economic and ecological costs of speed control bumps. It is also important to develop a complex of accident forecasting computer programs, a complex of methods of loss calculation for road traffic and a method to optimise decisions relating to the road traffic organization of typical objects on the basis of minimizing total losses. Different methods of accident forecasting define the methodical level of activity for improving road traffic safety. The methods (fig. 1) and the areas of information they use are shown in detail (fig. 2).

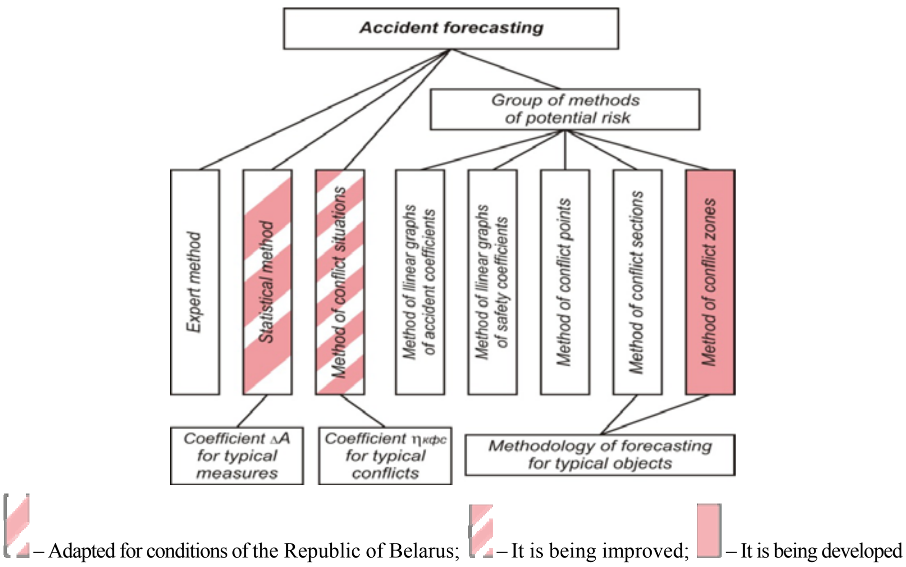

Figure 1. Classification of accident forecasting methods

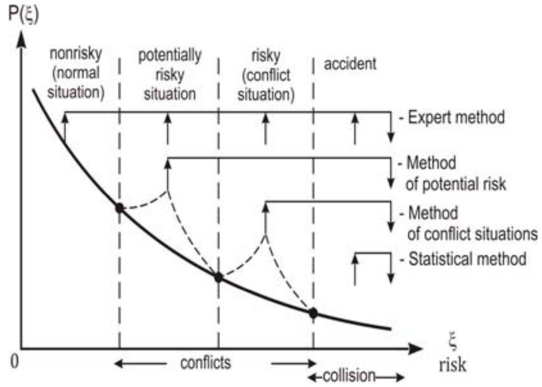

Figure 2. Areas of information used by various methods for accident forecasting

2. Methodology of Road Traffic Engineering

It has been shown that the existing methods of accident forecasting for urban conflict objects are unsuitable for use by the decision-making section. The 'Conflict areas' method is an exception. However, it is characterized by the low accuracy of its forecasts, which make it unsuitable for use for practical work relating to road traffic organization.

There is a problem of choice regarding the criteria for estimating road traffic quality. The discrete criteria used to estimate the different aspects of basic road traffic properties (crashes, economic factors, ecological aspects, social issues – [1]) are not interconnected themselves and cannot be used to estimate road traffic quality as a whole. Consequently only two complex estimated criteria can be applied – the 'grade of service' giving an estimation of different criteria of quality, and 'losses in road traffic' giving a quantitative (monetary) estimation. Both criteria have advantages and disadvantages and require further development and possible unification.

Methods to instigate a relative improvement in traffic safety can be divided into 4 sections: receiving the initial data; determining the reasons for the accident and making decisions about how to eliminate them; estimating the efficiency of the accepted decisions and optimizing them; and developing and introducing measures.

In the system under research, the following expenses are considered: crash costs (for all accidents; with and without victims), economic costs (delays, stops, transport overrun and fuel over-expenditure, delays and pedestrian overrun) and ecological costs (exceeding the minimum possible level of emissions of harmful substances into the atmosphere), and transport noise. In order to calculate the losses according to the choice of criteria, an optimization of the accepted decisions is made. It is necessary to be able to calculate (predict) all considered costs and to have sufficient initial qualitative data. However, the process of obtaining the initial data is time-consuming, expensive and imprecise because of the almost total absence of automation and equipment. A focal analysis technique, developed within the framework of the research, is used for defining the reasons for accidents and decision-making regarding their elimination,. After the decision has been accepted, an estimation of its efficiency is made, including a calculation of the economic, ecological and crash losses by means of the methods that have been worked out. At this stage, in order to create a procedure for calculating crash losses, it is necessary to develop a new and more exact 'conflict zones' accident forecasting method [2,3], individual accident forecasting techniques based on the method of 'conflict zones' at signalized intersections and at speed control bumps, and a technique for calculating the total cost of accidents in the Republic of Belarus. After the decision efficiency has been estimated, it is optimized on the basis of minimizing total losses using the computer programs developed for loss calculation and for optimizing decisions regarding signalized intersections and speed control bumps [4,5,6].

While introducing the measures worked out on the basis of making and optimizing decisions, an operative control estimation of crash efficiency is made using techniques developed in dissertational research into an improved method of accident forecasting for conflict situations. At this point, an operative updating of the measures is possible directly in the introduction process.

The initial data for analysis and accident forecasting, for calculating losses and for the optimization of decisions can be divided into 5 groups: accident statistics; geometrical characteristics; regulation and provision of the necessary facilities; road conditions; and transport and pedestrian load. A list of the necessary initial data, some requirements of the data and methods of its colletion, and also separate reference data are given.

A special technique of accident focal analysis in urban areas is developed. It includes the detection of acidentsites (places where there is a concentration of not less than 3 accidents per year), an estimation of the total seriousness of the consequences of the accidents using a modified technique, a preliminary determination of reasons using a devised list of typical reasons, an obligatory natural investigation of the accident site using a special technique, the final determination of the reasons following the natural investigation and a making a decision about how to eliminate the reasons for the accident using the devised list of typical suggestions in which the preliminary crash, and economic and ecological efficiency are shown. For these purposes, research into adapting the statistical method of accident forecasting to the urban conditions of the Republic of Belarus has been carried out in regard to speed control bumps, as the statistical information available is very inconsistent and the coefficients of the accident reduction differ by up to 3 times. On each conflict and linear object forms of safety audit are developed (fig. 3–10).

Survey (audit) sheets of an elementary section

Audit of safety in accident sites — Survey sheet: 1 (

The name of elementary street section (mid-block unsignalized pedestrian crossing):	

Audit is carried out: ______________ Date: ________

The audit (survey) sheet can be added according to the specificity of an accident site. Drawings are applied to the audit sheet in scale 1:500, and photo and video data are attached too.

№	Descriptive characteristics	Value, answer, mark	Notes
	Provision of the necessary facilities, condition and functionality of the section		
1.	Location of the pedestrian crossing; does its geometry coincide with the trajectory of the pedestrian traffic on approaches to it?		
2.	Where and how are the basic activity centers of pedestrians located? How do they influence on the work of the pedestrian crossing?		
3.	Presence of a curb. Is the curb high? Is there its lowering for the handicapped, children's carriages, the elderly and children? Condition of the curb.		
4.	Presence of a safety island. What is its kind? Is it protected and how?		
5.	Is the width and length of the safety island sufficient? Is it convenient and safe to be on it?		
6.	Do pedestrians use the safety island? If not, why?		
7.	Does the safety island channelize vehicle movement in the place of the pedestrian crossing?		
8.	Presence of the pedestrian fence. Their condition (if there are passes, breaks, etc. in them)		

Figure 3. The form of a mid-block unsignalized pedestrian crossing audit

Audit of safety in accident sites — Survey sheet: 1 (B)

The name of an elementary street section (mid-block signalized pedestrian crossing):	

Audit is carried out: ______________ Date: ________

The audit sheet (survey) is added by the following questions, except Sheet 1 (A), and also can be added according to the specificity of an accident site.

№	Descriptive characteristics	Value, answer, mark	Notes
	Conditions of visibility and traffic		
1.	Where and how do pedestrians wait for the green signal?		
2.	Where do vehicles stop on the red signal? Is the distance between vehicles and pedestrians sufficient?		
3.	How are pedestrians informed about the type of the signal control of pedestrian traffic (a kind of the change interval for pedestrians)?		
4.	Do pedestrians go strictly on the green signal? If not, how and why?		
5.	How do pedestrians begin and finish their traffic? Are there cases of their traffic on the red signal at the end of the pedestrian phase?		
6.	Is the change interval sufficient? As a result of the nonsufficient change interval pedestrians have to stop on the safety island or to go on the red signal, or to finish their pass by running.		
7.	Are there cases of conscious pedestrian traffic on the red signal? How often and why does it happen?		
8.	Are there cases of conscious vehicle movement on the red signal? How often and why does it happen?		
9.	Do pedestrians pass the street in one stage or in two (especially when a protected safety island or a central median are present)?		

Figure 4. The form of a mid-block signalized pedestrian crossing audit

Audit of safety in accident sites — Survey sheet

The name of an elementary street section (unsignalized/signalized intersection):	

Audit is carried out: ______________ Date: ________

The audit (survey) sheet can be added according to the specificity of an accident site. Drawings are applied to the audit sheet in scale 1:500, and photo and video data are attached too.

№	Descriptive characteristics	Value, answer, mark	Notes
	Provision of the necessary facilities, condition and functionality of the section		
1.	Location of pedestrian crossings and stations of public transport, their influence on the intersection operation.		
2.	Where and how are the basic activity centers of pedestrians located? How do they influence on the intersection operation?		
3.	Width of the carriageway and its lanes.		
4.	Rounding-off radiuses of the carriageway and its adjunctions.		
5.	Presence of slopes on the approaches.		
6.	Is there a wrong adjunction of the road cutting of crossing streets and an adjunction with tram lines?		
7.	Are there unwanted objects on the carriageway, especially such as building materials, details of vehicles, water, mud, rubbish etc.?		
8.	Are there damages of the carriageway, such as pot-holes, large fissures, slumps?		
9.	Are there numerous raised or lowered manholes, lattices, ventilation pipes, often uncovered or damaged?		
10.	Is there a contrasting pavement of the carriageway informing drivers (pedestrians) about borders of the intersection (pedestrian crossings, etc.)?		

Figure 5. An intersection audit form

Audit of safety in accident sites — Survey sheet: 1

The name of an elementary street section (mid-block underpass/pedestrian footbridge):	

Audit is carried out: ______________ Date: ________

The audit sheet (survey) is added by the following questions, except Sheets 1 (A) and 1 (B), and also can be a according to the specificity of an accident site.

№	Descriptive characteristics	Value, answer, mark	Notes
	Provision of the necessary facilities, condition and functionality of the section		
1.	Is the pedestrian crossing convenient (especially the descent/rise in/on it)?		
2.	Is the pedestrian crossing equipped with a ramp (lift)? Is it comfortable for using?		
3.	Are there at the pedestrian crossing any activity centers of the pedestrian? And how are they used? Do they impede for the pedestrian traffic?		
4.	Is the pedestrian crossing clean? Is there rubbish, dirt, water etc. in it?		
	Conditions of visibility and traffic		
5.	Are ladders, ramps and the pedestrian crossing itself well illuminated?		
6.	Are there cases when pedestrians have to move in the opposite to the activity centre direction (overpass)? How long is this distance? Why does it occur?		
7.	Are there cases of refusal by pedestrians to use the underpass/ pedestrian footbridge? How often does it occur and why?		

Figure 6. An underground crossing and an overground crossing audit form

Audit of safety in accident sites **Survey sheet: 2**

The name of an elementary street section (station of public transport):	________________

Audit is carried out: ________________ Date: ________

The audit sheet (survey) is added by the following questions, except Sheets 1 (A) and 1 (B), and also can be a according to the specificity of an accident site.

№	Descriptive characteristics	Value, answer, mark	Notes
	Provision of the necessary facilities, condition and functionality of the section		
1.	Location of the station. Is the station comfortable for the passenger and driver of the public transport use?		
2.	Is the station equipped by a pavilion, benches, rubbish bin? Are they comfortable for use?		
3.	Is there a special widening of the road surface? And how is its area used? What is it (closed, opened, on a combined additional lane)? And is there compelled maneuvering? What kind of maneuvering is it? Is it dangerous?		
4.	Length, width, parameters of the special widening of the road surface for the public transport.		
5.	How does the stopped public transport influence on the traffic of other transport in case of the absence of a special widening of the road surface? Is there compelled maneuvering? What kind of maneuvering is it? Is it dangerous? Are there conflict situations "transport – transport"?		
6.	Where and how are the basic activity centers of pedestrians (passengers) located? How do they influence on the work of the station?		
7.	How far is the pedestrian crossing located from the station? Is it comfortable for use?		
8.	Presence of a curb. Is the curb high at the station? The condition of the curb.		

Figure 7. The form of a public transport station audit

Audit of safety in accident sites **Survey sheet: 2 (B)**

The name of an elementary street section (tram station):	________________

Audit is carried out: ________________ Date: ________

The audit sheet (survey) is added by the following questions, except Sheets 2 (A) and also can be added according to the specificity of an accident site.

№	Descriptive characteristics	Value, answer, mark	Notes
	Provision of the necessary facilities, condition and functionality of the section		
1.	Is the width of the boarding area (if it exist) sufficient and is there any danger of an unexpected exit of pedestrians on the carriageway from the both sides (i.e. are they fenced from the carriageway)?		
2.	Is there a possibility of vehicle movement on a tram line?		
3.	What is the condition of the tram line?		
	Conditions of visibility and traffic		
4.	How do pedestrians (passengers of the tram) interact with the oncoming transport?		
5.	Are there cases of a premature exit of pedestrians on the carriageway, long before the tram arrival, forcing vehicles to stop urgently?		
6.	Are there cases when the station is located before the intersection and passengers have to get to a tram (or to get out of it) through compactly staying transport?		
7.	Is the refuge well visible to the drivers of vehicles?		
	Traffic management		
8.	Are there any traffic signals regulating the movement of trams?		

Figure 8. The form of a tram station audit

Audit of safety in accident sites **Survey sheet**

The name of an elementary street section (stage, line section):	________________

Audit is carried out: ________________ Date: ________

The audit (survey) sheet can be added according to the specificity of an accident site. Drawings are applied to th audit sheet in scale 1:500, and photo and video data are attached too.

№	Descriptive characteristics	Value, answer, mark	Notes
	Provision of the necessary facilities, condition and functionality of the section		
1.	Are there pot-holes, waves, affluences, combs, abysses, fissures, dents, ruts, the local slumps, raised or lowered manholes, lattices, ventilation pipes, etc, on the carriageway?		
2.	If a tram line is present or curb is absent – what is the condition of edges, the quality of the joint with the carriageway?		
3.	What are roughness, polishing, sweat, dirt covering, water stagnation, and icing or uncleared snow in winter?		
4.	Presence and condition of the curb.		
5.	Presence of a congestion of a mud, rubbish and irrelevant objects around the curb.		
6.	What is the condition of sidewalks, lawns, approaches and exits to the carriageway?		
7.	What is the condition of the stations of public transport and parking areas?		
8.	Is there a rounding-off radius and what is its value?		
	Conditions of visibility and traffic movement		
9.	Presence, location and condition of lawns.		
10.	Presence and location of trading stands, billboards, public telephones, etc.		

Figure 9. The form of a linear section audit

Audit of safety in accident sites **Survey sheet: 5**

The name of an elementary street section (railway crossing):	________________

Audit is carried out: ________________ Date: ________

The audit (survey) sheet is added by the following questions, except Sheet 1 (A), 2(A), 3 or 4. It also can be added by other questions according to the specificity of an accident site. Drawings are applied to the check sheet in scale 1:500, and photo and video data are attached, too.

№	Descriptive characteristics	Value, answer, mark	Notes
	Provision of the necessary facilities, condition and functionality of the section		
1.	Are there lawns? Their location and condition		
2.	At what angle do the street and the railway line cross each other (at an acute angle or after sharp turn of the road)?		
3.	Are there intersections, joinings, turns of the street, slopes in front of the crossing?		
4.	How even are the carriageway and floorings on a railway crossing?		
5.	How is the railway crossing highlighted (more detail for a low category)?		
6.	Is there any control (traffic lights, barriers, physical restriction of the entrance on the railway crossing)?		
	Conditions of visibility and traffic		
7.	What is the lateral visibility in the conflict 'transport – train' (including the presence of separate obstacles within a visibility triangle)?		
8.	What is the visibility of traffic signals on crossing without a barrier?		
9.	What is the illumination of the railway crossing? Presence of artificial lighting of the approaches to the crossing.		
10.	How is pedestrian traffic carried out over the crossing?		

Figure 10. The form of a railway crossing audit

The 'conflict zones' accident forecasting method and the individual techniques of accident forecasting for typical objects, the new techniques of accident cost definition in the Republic of Belarus and the advanced individual design procedures for emergency, economic and ecological losses in road traffic, which are based on it –allow estimations of efficiency to be carried out and the accepted decisions to be optimized on the basis of minimizing total losses in order to increase the safety of road traffic at the location for which the calculations have been made. All these methods comprise the methodology for improving road traffic safety at urban accident sites.

3. Practical Realization of the Developed Positions

On behalf of the State Motor Vehicle Inspectorate, the Scientific Centre for Road Traffic Research has carried out work on the preparation of preproject design regarding increasing the safety and decreasing the losses in road traffic on K.Tsetkin Street in Minsk between the intersection (a roundabout) of Nemiga St. – Dzerzhinskogo Ave. – Tsetkin St. (Bogushevich Square) and the intersection of Tsetkin St. – Kalvarijskaya St.

According to the peculiarities of the road traffic conditions and the scheme of the road traffic organization, the part of investigated Tsetkin Street being investigated is divided into 12 characteristic sections (linear and conflict objects in the road network) [3,7,8].

- Object 1 (conflict) – signalized pedestrian crossing of Tsetkin St. at the junction of the circular carriageway of Bogushevich square;
- Object 2 (linear) – section from the signalized pedestrian crossing in Bogushevich square to signalized T-shaped intersection with Libkneht st.;
- Object 3 (conflict) – signalized T-shaped intersection with Libkneht St.;
- Object 4 (linear) – section from the signalized intersection with Libkneht St. to the signalized pedestrian crossing near building № 18 (near "GALANTEYA" Co);
- Object 5 (conflict) – signalized pedestrian crossing near building № 18;
- Object 6 (linear) – section from the signalized pedestrian crossing near building № 18 to the unsignalized pedestrian crossing near building № 49 (Enterprise "Gorremavtodor");
- Object 7 (conflict) – unsignalized pedestrian crossing near building № 49;
- Object 8 (linear) – section from the unsignalized pedestrian crossing near building №49 to the intersection with an exit from the platform of the communal machinery (the storehouse of the enterprise "Gorremavtodor");
- Object 9 (conflict) – unsignalized T-shaped intersection with an exit from the platform of communal machinery;
- Object 10 (linear) – section from the intersection with the exit from the platform of communal machinery to the intersection with Korolya St.;
- Object 11 (conflict) – unsignalized T-shaped intersection with Korolya St. and an unsignalized pedestrian crossing.
- Object 12 (linear) – section from the intersection with Korolya St. to the intersection with Kalvarijskaya St.

On each section an accident analysis is made (using the data provided by the State Motor Vehicle Inspectorate (data about road accidents resulting in injury and road accidents resulting in material damage).

It is necessary to notice that the quality of the initial data is low because of their incompleteness and (in many cases) lack of authenticity. Unfortunately, the absence of all-the-year-round data regarding traffic volume, traffic speed, the conditions of road surfaces etc. does not allow the relationship between the volume of traffic and the quantity of accidents to be revealed; allowing the most dangerous months of the year, days of the week and times of the day to be understood.

The presence of more qualitative data including the results of accident investigations that indicate all the concomitant factors, would certainly allow the analysis of reasons for accidents to be more exact, and would allow an expansion of the list of possible measures which could promote a reduction in the accident rate in the street section being investigated and on other urban streets. To enable this it is necessary to improve the system of road traffic monitoring and to carry out site accident analysis in the regional department of State Motor Vehicle Inspectorate. As a result the site accident analysis would be more complete and include the elements of a road safety audit.

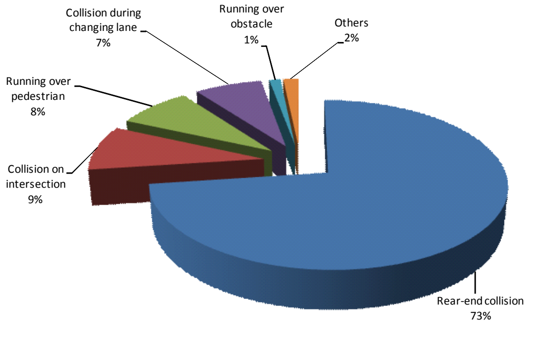

Figure 11. Distribution of accidents by type

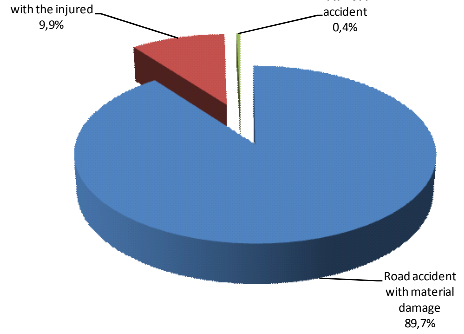

Figure 12. Distribution of accidents by the seriousness of their consequences

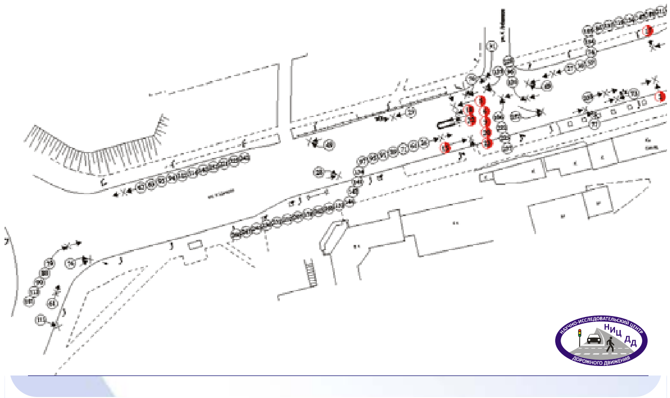

Figure 13. Accident focal analysis

The accident focal analysis is executed and basic laws of traffic accident occurrence are established.

One can see that the number of accidents is caused by the absence of an dedicated lane for the left turn transport only. Some accidents have occurred because of incorrect estimations of the intervals in traffic flow of the opposing transit traffic direction while turning left. This circumstance stipulates also the absence of a separate phase in the traffic light cycle for the movement of left turning traffic. The regulation is organized by the 'infiltration' method.

One can also notice that more than 84 % of accidents happen as a result of rear-end collisions which occur before pedestrian crossings, basically, working in signalized mode. It is explained by the fact that drivers need to distinguish the moment of decision-making by the driver of the car in front: whether to brake or to go on moving. It is probable that drivers are slow to pay attention to traffic light signal changes while moving in a high-loaded traffic flow. This can happen, for example when moving in the second or third lane. The signals of the basic traffic light may not be not visible because of a large-sized vehicle, and the changing road traffic situation make it very difficult to locate a different set of lights.

An analysis of road traffic organization and traffic conditions is made. This includes: experimental research into pedestrian and traffic flows; research into load level and the throughput; analysis of the triangle of lateral visibility and its transparency, and also of the activity centers of pedestrians, in order to substatiate measures for increasing road traffic safety. The analysis of the disadvantages of the existing traffic conditions for each of the objects is made.

The diagram of the measurement traffic speed in different lanes at the time of movement of traffic flow from Bogushevich Square to Kalvarijskaya Street is presented in fig. 14.

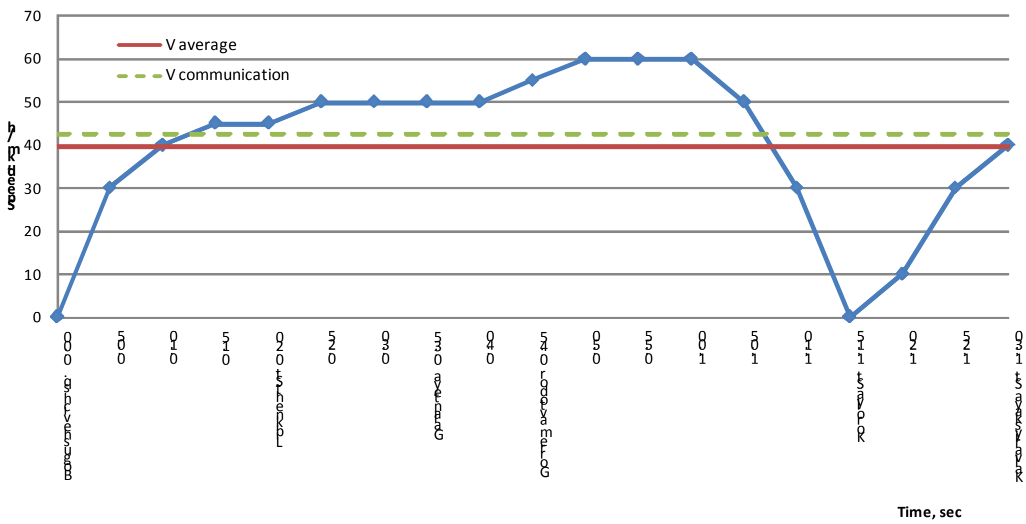

Figure 14. The diagram of traffic speed measurement for lanes at the time of movement of traffic flow from Bogushevich square to Kalvarijskaya street (2nd lane)

It is found out that the average traffic speed of cars is low, and that the fastest moving cars are in the third lane. The results investigating the speed of traffic flows from Kalvarijskaya St. to Bogushevich Square, and in the reverse direction, are presented in table 1.

Table 1. Traffic flow speed

Indexes	The moving direction					
	from Bogushevich Square to Kalvarijskaya Street			from Kalvarijskaya Street to Bogushevich Square		
	1st lane	2nd lane	3rd lane	1st lane	2nd lane	3rd lane
S, km	1,06					
Vcp, km /h	23,6	39,7	31,5	32	42,2	56,4
Vc, km /h	23,9	42,4	33,2	34,7	44,9	58,7
δ	0,01	0,06	0,05	0,08	0,06	0,04
d, sec/(veh.·km)	90,6	24,9	48,4	43,7	20,2	1,3
σ	21,2	18,3	25,4	20,3	23,4	11,7
I	0,9	0,46	0,81	0,63	0,55	0,21

One can see that the traffic speed in the first lane is characterized by lower values. The reason for this is public transport and volume of traffic in the first lane (including the location of placing public transport stops without a special widening of the road).

For each object, research into pedestrian activity centers (fig. 15) was conducted.

Research into pedestrian and traffic flows characteristics were carried out. The values of average traffic volume in lanes in various directions of movement are shown in fig. 16.

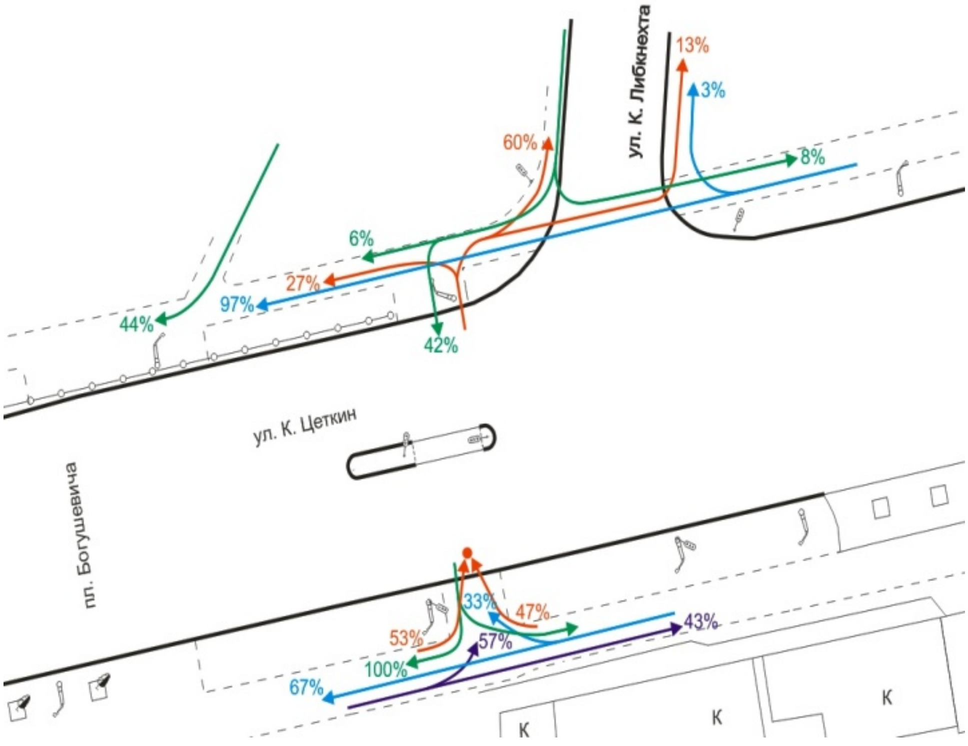

Figure 15. Distribution of pedestrian flow in directions (for object 3)

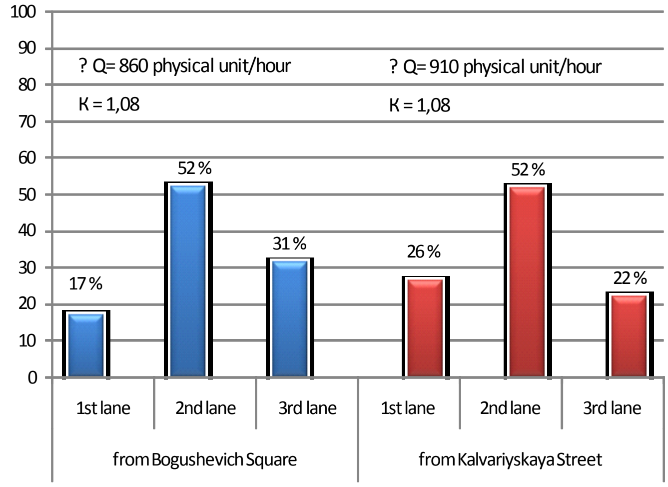

Figure 16. Distribution of average traffic volume in lanes

On the basis of the collected initial data, losses for the existing traffic conditions (tab. 2 and fig. 17) have been calculated.

Table 2. Calculation of road traffic losses for objects for the existing conditions

№	Name of parameters		Dimensionality	Value
1	The average annual number	of killed pedestrians	persons per year	-
2		of injured pedestrians	persons per year	-
3		of accidents with material damage	accidents per year	3,3
4	Specific number of accidents		accidents per million vehicles	0,29
5	Crash losses		1000 c.u. per year	2,7
6	Ecological losses		1000 c.u. per year	29,1
7	Economic losses		1000 c.u. per year	93,8
8	Total losses		1000 c.u. per year	125,6

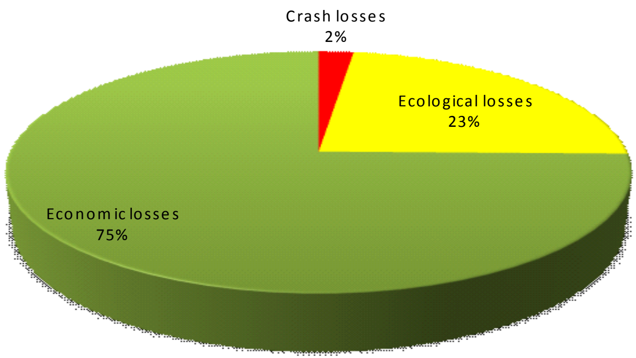

Figure 17. Distribution of losses for objects according to the type

The relative accident indices for the objects in Tsetkin Street according to road length are presented in fig. 18.

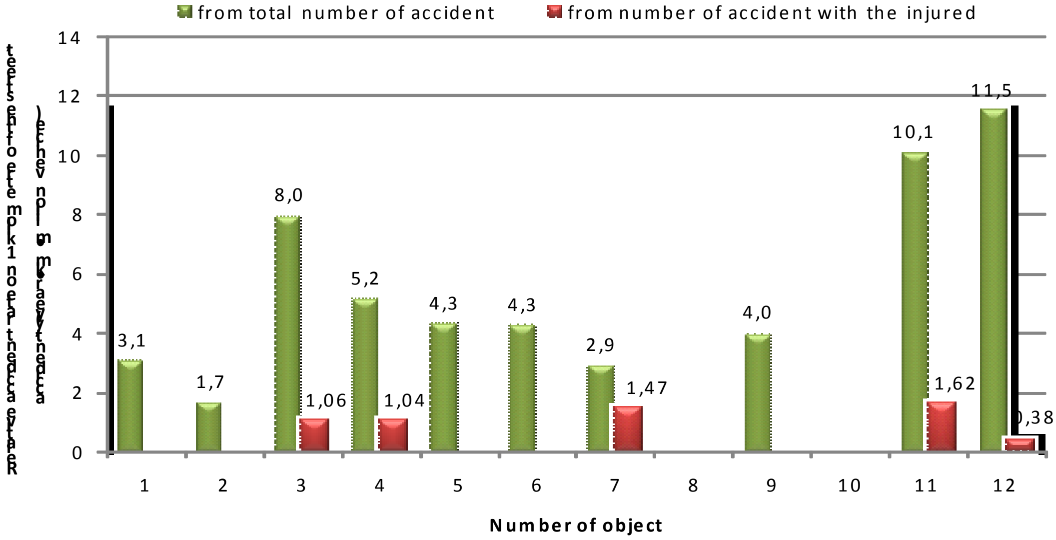

Figure 18. The relative accident indexes for the objects of the road network depending on road length

The losses referring to 1 km of a street for each elementary object are shown in fig. 19.

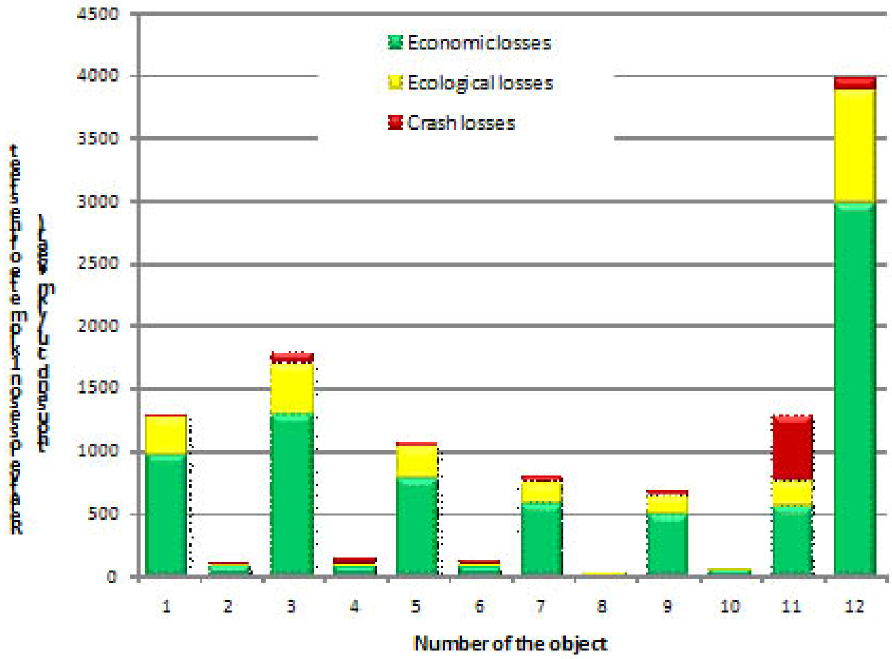

Figure 19. The correlation of the level of danger and losses in road traffic for investigated objects subject to street length

One can see that the sections where the increased level of losses is observed have conflict objects – pedestrian crossings (signalized and unsignalized) and signalized T-shaped intersections. This can be explained by the fact that a higher level of starting and stopping occurs around such objects, as well as by the conflict interaction of traffic flows with each other and the conflict interaction of traffic and pedestrian flows. A high level of traffic delays is observed because of the presence of signal control, or the requirement to let pedestrians cross in an unsignalized mode. Thus, economic, ecological and crash losses increase.

According to the results of investigations of traffic conditions and the characteristics of traffic and pedestrian flows the following disadvantages are found: (see fig. 20).

Figure 20. Some disadvantages found out during the investigations

Thus, the following suggestions for improving traffic conditions and increasing traffic safety on the investigated section of Tsetkin Street have been developed.

These suggestions have been developed on the basis of research conducted for the purpose of reducing the traffic losses. To achieve this, it is necessary to solve the following primary problems:

- Elimination of unsignalized 'transport – pedestrian' conflicts. These are characterized by an increased accident rate should not occur on an arterial route with 6 lanes;
- Elimination of unsignalized left turns in Tsetkin Street, freeing the left (the fastest-moving) lane from stationary vehicles waiting for an opportunity to turn left (or U-turn);
- Elimination of unsignalized left turns while entering Tsetkin Street;
- Minimization of the basic flow problems created by public transport.
- Improvement of traffic signal comprehension by means of placing the duplicating traffic signals in the zone of the best visibility, and the application of modern engineering solutions;
- Improvement of pedestrian movement conditions on signalized sections by means of applying modern traffic management equipment and adjusting the pedestrian signals' modes of operation;
- Installation of signalized objects in the places which could enable the possibility to organize a coordinated regulatory system for the investigated section of Tsetkin Street;
- Designation of the permitted moving directions for each lane in the entrances to Bogushevich Square (at the border of the investigated section);
- Creation of a barrier-free environment on pedestrian crossings;
- Organization of parking spaces away from the main traffic area of Tsetkin Street.

Task №1 is solved by the elimination of the existing unsignalized pedestrian crossings (with the organization of signalized pedestrian crossings on the signalized areas), and also by the organization (restoration) of the central pedestrian section, including the installation of a safety barrier on it to pevente pedestrians from crossing the street. The organization of signalized pedestrian crossings in 4 places is proposed: Bogushevich Square, Libkneht Street, near building №18, and the exit from the storehouse of the 'Gorremavtodor' enterprise. Other pedestrian crossings will be closed down. Taking into account the availability of the underground pedestrian crossing at the junction with Kalvariyskaya Street, the normative distance between the crossings (300 m for a street of A6 category, i.e. an arterial street with 6 lanes) is maintained.

Task №2 is solved by restoring of the central island configuration, which allows the creation of an additional lane for left-turn in the area of the intersection. It also allows the removal of left turns in other places. Additional lanes for the left-turning movement are offered at the intersections with Libkneht Street and the exit from the storehouse of the ‘Gorremavtodor’ enterprise. The left-turning movement connected with Korolya street and the passage to the State Motor Vehicle Inspectorate will be reorganised.

Task №3 is solved by restoration of the central islandin which gaps are provided only where there are crossings with signal control (intersections with Libkneht Street and from the storehouse of the Gorremavtodor enterprise. This task is realised by the reconstruction of all the exits (rounding-off the radiuses) on Tsetkin Street according to the Construction Regulations of Belarus 3.03.02 and by the organization of a guiding island on the intersection with Korolya Street for traffic ordering.

Task№4 is solved by placing all public transport stations and stops (with no exception) only in areas where the road has been especially widened. Consequently the ‘Galantereynaya’ stop in the direction of Kalvarijskaya Sreet will be moved to a new location near the State Motor Vehicle Inspectorate.

Task №5 is solved by placing duplicating traffic signals on the restored central island at all signalized objects, and also by the application of traffic signals for vehicles with multipurpose additional sections at the entrance to Bogushevich Square and by correcting the pointer direction in the right additional sections for the conformity of a real entrance configuration.

Task №6 is solved by the application of pedestrian traffic signals (with pedestrian countdown signals) on pedestrian crossings and by updating the operating modes of pedestrian signals for maintenance of an interjacent interval for pedestrians in the ‘pedestrian-transport’ interphase conflict for all signalized objects.

Task №7 is solved by placing signalized sections at distances which will allow the organization of the coordinated operating of adjacent signalized objects. The proposed signalized sections are: the pedestrian crossing on the approach to Bogushevich Square, the intersection with Libkneht Street, the pedestrian crossing near building №18, the intersection exit from the ‘Gorremavtodor’ storehouse, the intersection with Kalvarijskaya Street. The distance between the entrance stop-lines of the signalized objects comes to 300-500 m. This allows coordinated regulation to be realized.

Task №8 is solved by installing the road signs 5.8.1 and the pavement horizontal marking 1.18 on the approach to Bogushevich Square (instead of an interweaving area, as with the existing scheme of traffic organization).

Task №9 is solved by installing curbs with a reduced height on the approaches to pedestrian crossings from sidewalks and on the safety islands of all signalized pedestrian crossings. It’s also solved by creating sidewalks and by the separation of cyclists’ and pedestrians’ movements by means of pavement markings and the installation of road signs.

Task №10 is solved by organizing parking spaces on the lateral median between the traffic area and sidewalks (with a parking angle of 45-60 degrees), and also having isolated parking places on free areas. The organization of visitor parking at the Gorremavtodor enterprise and office buildings in Korolya Street is possible only with an entrance directly from the traffic area at the angle of 60 degrees, and parking between the trees. At the building of the State Motor Vehicle Inspectorate the organization of isolated parking is also possible. While organizing the parking places, normative triangles of visibility before the intersections and pedestrian crossings should be provided. It is also recommended that the configuration of the sections adjoining the trees trunks be changed and kept free of charge in order to increase the quantity of parking places at the real angles of the entrance – exit (45-60 degrees) (in fig. 21).

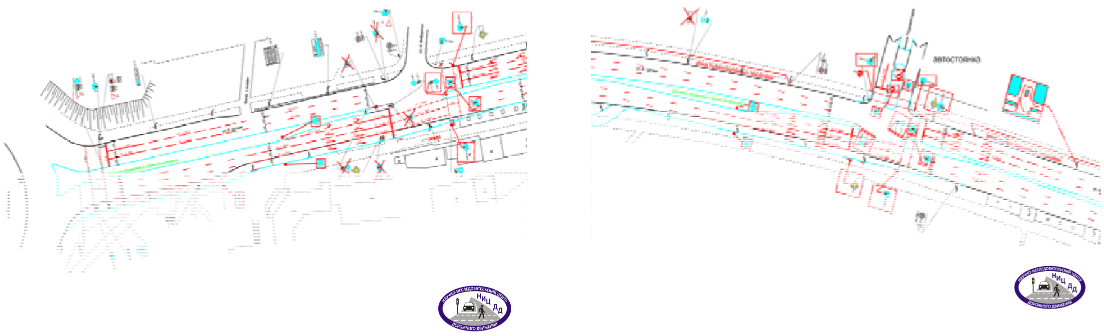

Figure 21. Some suggestions on perfection of the road traffic organization

For each proposed economic decision, ecological and crash losses (fig. 22) have been defined. Then, on each investigated object less costly measures have been chosen (road marking, installation of traffic signs, reprogramming of signal control modes by the road controller, separation of left turn lanes by road markings, etc.). Losses which have been calculated for less costly measures are compared with the benefits from decreasing the losses after the realization of more capital-intensive measures (fig. 23) (the cost of building introduced measures is estimated by comparison with similar projects). It is evident that the more costly variant of traffic conditions improvement will pay off later, but while increasing the traffic load it will not cause a deterioration of the traffic conditions and will promote safe movement for traffic and pedestrian flows (while minimising economic, ecological and crash losses).

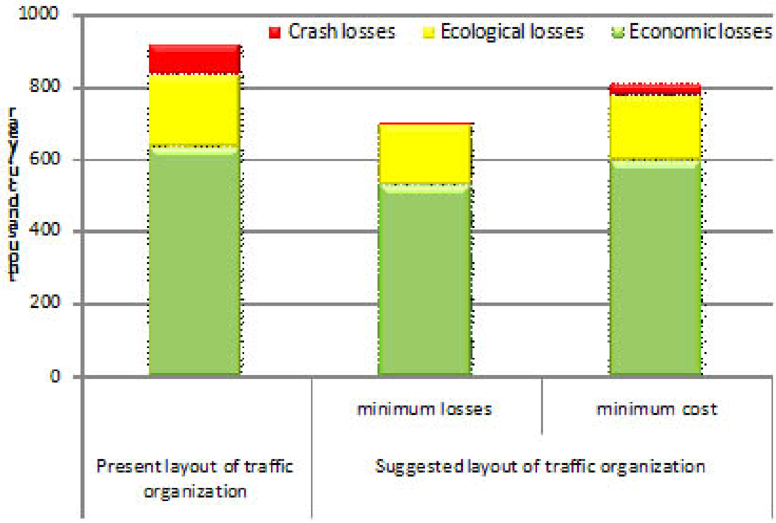

Figure 22. Losses in road traffic according to the variants of offered decisions

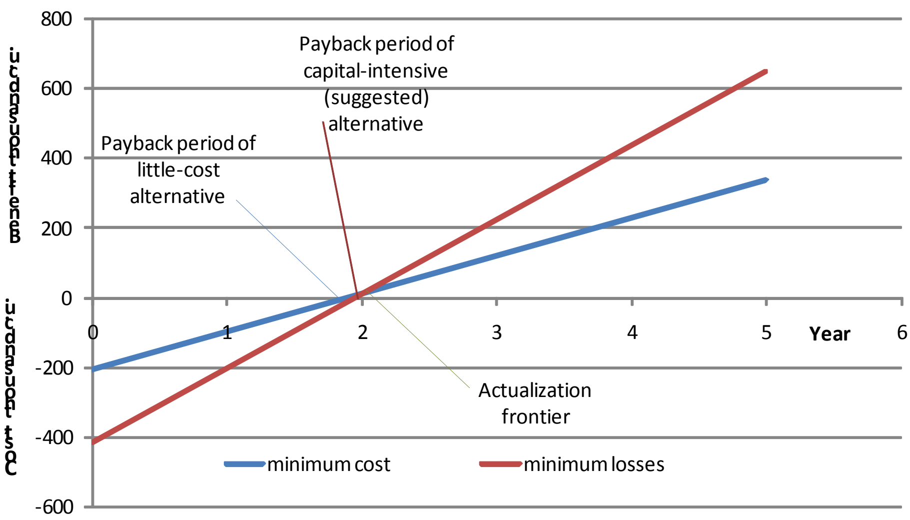

Figure 23. Expediency of the introduced measures

Variants of design decisions are accepted by the customer for the further introduction.

4. Conclusions

Thus, it is possible to state that the developed methodology for improving traffic safety at the accident sites allows solutions to be found to the total complex of the problems relating to the choice of the optimal decisions directed to the improvement of road traffic quality as a cumulative attribute (taking into account equations of crash, ecological and economic losses).

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