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Development of information system of automatic control of operation of the traffic light on the basis of the analysis of a transport stream

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ANNOTATION

Cars on the roads become larger every year, cities literally choke on the influx of cars. At the same time, there are many claims to the roads themselves: poor quality, inconvenient road interchanges, lack of overground / underpasses and bypass roads for freight trucks. The problem of traffic congestion on the roads requires a solution - the sooner, the better as for an individual whose time is wasted, and for the economy of the country as a whole. And this problem is not only for Kazakhstan - it is estimated that about 11 billion of fuel is spent in the US for a year, about 4.2 billion hours are lost, and losses are measured in tens of billions of dollars!

To date, one of the main problems of large cities of Kazakhstan, in particular Almaty, are automobile congestion (traffic jams). Automobile jams cause huge damage to the environment. Exhaust gases contain about 200 chemical compounds. During the idle time of a large number of cars in a jam, there is a large release into the atmosphere, which causes invaluable damage to the environment and the health of citizens living in the contaminated city. Also, congestion is the cause of nervous disruption of citizens. Most motorists are idle in traffic jams for more than two, or even three hours a day. The constant tension behind the wheel, the inhalation of exhaust gases, the loss of time in congestion - all this adversely affects the physical and moral condition of people using cars.

On the other hand, traffic management is a very non-trivial task, because although the object is the traffic flow consisting of technical means, in fact one has to manage living people, each of which pursues its goals. In some cases, management is limited to recommendations that an object may not follow. For example, speed is often limited only from above, and in Almaty many drivers perceive the red light only as a recommendation to stop! In addition, it is often difficult to choose quality management criteria. And transport work, and the delay at intersections, and the speed of communication, and the number of traffic accidents, and the amount of harmful emissions, it can be said, are equally important.

Key words: *traffic light, transport, traffic, traffic jams, optimize, time, cars, statistics, development, evolution.*

ТҮЙІН

Жолда автомобильдер жыл сайын үлкен болып, қала сөзбе көліктердің ағыны бастап тұншығу отыр. Сонымен қатар мен көптеген шағымдарды жолдар арқылы: сапасыз, ыңғайсыз жол айрығы, жер үсті / жер асты өткелдері және жүк вагондарын үшін айналма жолдар болмауы. кептеліс проблемасы шешілуі қажет - ерте, оның уақыт ысырап, және тұтастай алғанда экономика үшін болып жеке тұлға үшін жақсы. Ал бұл мәселе Қазақстан үшін ғана емес -! Ол Америка Құрама Штаттарында жылына арналған, отын шамамен $ 11 млрд жұмсалды шамамен 4,2 млрд сағат жоғалтып, мен залалдар миллиардтаған доллар ондаған бағаланады деп бағаланады

Бүгінгі күні, атап айтқанда Қазақстан, Алматы ірі қалалардың басты проблемалардың бірі кептеліс (джемдер) болып табылады. Кептеліс қоршаған ортаға орасан зор зиян келтіруі. пайдаланылған газ 200-ге жуық химиялық қосылыстар бар. пульпа машиналар үлкен санының тоқтату барысында, атмосферада үлкен шип ластанған қалада тұратын азаматтардың қоршаған ортаға және денсаулығына жетпес залал келтірген, бар. Шоғырланған, сондай-ақ жүйке іркілістер азаматтарын тудыруы. тасымалдарда жұмыс істемейтін Ең автоәуесқойларға астам екі немесе тіпті үш сағат бойы ашыңыз. пайдаланылған түтін деммен жұту тұрақты кернеу жүргізу, кептелісте уақыт босқа - барлық осы вагондарды пайдалану адамдардың физикалық және моральдық жай-күйі туралы теріс әсер етеді.

Екінші жағынан, қозғалысын басқару - өте тривиальная міндет, нысан аппараттық тұратын көлік ағыны болып табылады, тіпті, өйткені, шын мәнінде, оның мақсатын көздейді, олардың әрқайсысы, адамдарды басқару үшін қажет. Кейбір жағдайларда, бақылау объектісі кейіннен мүмкін емес ұсынымдар шектеледі. Мысалы, жылдамдық жиі ғана жоғарғы шектелген, және Алматы қаласында көптеген драйверлері ғана қалуға ұсыныс ретінде қызыл жарық қабылдайды! Сонымен қатар, ол сапаны бақылау өлшемдерін таңдау жиі қиын. Ал көлік жұмысы, кешігу және байланыс жылдамдығы, және жол-көлік оқиғалары мен зиянды шығарындылар мөлшерін санының қиылысында, біз бірдей маңызды айтуға болады.

Кілт сөздер: *бағдаршам, көлік, жол қозғалысы, кептеліс, оңтайландыру, уақыт, автомобильдер, статистика, дамыту, эволюциясы.*

АННОТАЦИЯ

Машин на дорогах становится больше с каждым годом, города буквально задыхаются от наплыва автомобилей. При этом и к самим дорогам претензий много: плохое качество, неудобные автомобильные развязки, отсутствие надземных/подземных переходов и объездных дорог для грузовых фур. Проблема пробок на дорогах требует решения - чем скорее, тем лучше как для отдельного человека, чье время тратится впустую, так и для экономики страны в целом. Причём проблема эта не только для Казахстана – подсчитано, что в США за год тратится около 11 млрд горючего, теряется около 4,2 млрд часов, а убытки измеряются десятками млрд долларов!

На сегодняшний день одна из главных проблем крупных городов Казахстана, в частности Алматы, являются автомобильными заторами (пробки). Автомобильные заторы наносят огромный ущерб экологии. В выхлопных газах содержится около 200 химических соединений. Во время простоя большого количества машин в заторе, идёт большой выброс в атмосферу, что наносит неоценимый ущерб окружающей среде и здоровью граждан, проживающих на территории загрязненного города. Также заторы являются причиной нервных срывов граждан. Большинство автолюбителей простаивают в пробках больше двух, а то и трех часов в день. Постоянное напряжение за рулем, вдыхание выхлопных газов, потеря времени в заторах - все это пагубно влияет на физическое и моральное состояние людей, пользующихся автомобилями.

С другой стороны, управление дорожным движением – весьма нетривиальная задача, потому что, хоть объектом и является транспортный поток, состоящий из технических средств, фактически приходиться управлять живыми людьми, каждый из которых преследует свои цели. В ряде случаев управление ограничивается рекомендациями, которым объект может и не последовать. Скажем, скорость зачастую ограничивается только сверху, а в Алматы многие водители воспринимают красный свет лишь как рекомендацию остановиться! Кроме того, зачастую трудно выбрать критерии качества управления. И транспортная работа, и задержка на перекрестках, и скорость сообщения, и число дорожно-транспортных происшествий, и объем вредных выбросов, можно сказать, одинаково важны.

Ключевые слова: *светофор, транспорт, движение, пробки, оптимизация, время, автомобили, статистика, развитие, эволюция.*

CONTENTS

INTRODUCTION

Transport - the most important part of the infrastructure of countries and, in particular, cities. Its stable and efficient functioning is a necessary condition for high and stable rates of economic growth, ensuring integrity, national security, and improving the living standards of the population.

The history of urban development points to a close relationship between the development of cities and the transport system. This is explained by the specificity of a person's life in the conditions of a modern large city, when it is necessary for a person to visit various facilities to meet his various needs. In addition to individual human needs, transport, serves various branches of the national economy. An analysis of the development of cities shows that there is a very close relationship between the size of their territories and the means of communication.

Le Corbusier argued that no city could grow faster than its transport grows. The French specialist in the field of transport V. Favre d'Arye identifies three main stages in the development of urbanization: first, transport links offer opportunities for the development of the city; Secondly, the result of the development of the transport network is the improvement of the quality of service; Thirdly, improving transport services contributes to further urbanization. In addition, the transport network forms the planning structure of the city, being its frame. Throughout the history of urban development, there is a process of reducing the linear density of the transport network while maintaining its quadratic density. This process is associated with the continuous improvement of vehicles, their differentiation in purpose and leads, in general, to an increase in the area of neighborhoods and neighborhoods.

For proper implementation of the linking, communication and support functions, it is necessary to carry out a quality management of the transport system.

The management of traffic flows is one of the most important tasks of modern megacities. In fact, urbanization, together with the development of the motor transport industry, has led to the emergence of huge flows of cars moving along the streets of modern large cities. In this connection, the large accumulation of cars in conditions of limited - to a large extent already established - road and transport infrastructure leads to congestion on the roads, and as a result, to forced delays in supply chains. The latter, in turn, entails serious losses in the economy. This fact, along with many others, entails the need for the formation of management strategies and concepts for the management of transport flows and their redistribution.

The first cities in the world, faced with the problem of congestion and traffic jams on the roads, were New York and Tokyo. Naturally, at the moment these cities have the most significant experience in solving road and transport problems. Among other megacities, solving such problems at a sufficiently high level, it is necessary to first of all allocate Seoul, London, Singapore, Melbourne and Los Angeles. In all these cities, along with methods that take into account the specifics of megacities, common approaches to freeing streets from congestion were applied. When analyzing the accumulated experience, it should be remembered that most of the existing methods of combating congestion rely on some kind of intellectual base, which has been formed for almost a hundred years of this problem. Today there is an extensive literature on the study and modeling of motor transport flows. Several academic journals are devoted exclusively to the dynamics of the automobile movement.

Thus, the relevance of the theme of the dissertation work is that in the conditions of world urbanization, as well as the growth of the number of megacities, the issue of managing traffic flows, unloading streets from constant congestion and ensuring road safety becomes more acute. In addition, the rapid growth in the number of cars on the roads also leads to a deterioration of the ecological situation in large cities.

It should be noted that at the moment there is already a serious, but at the same time constantly evolving, intellectual basis for investigating modern problems of managing traffic flows.

If you look at the problem globally, it is often necessary to use infrastructural methods for managing traffic flows in large cities: construction of interchanges, metro, restrictions on the movement of vehicles at certain times, etc. However, this is a very long process and in general, it requires large investments. One of the fastest and most easily implemented methods for solving the above problems is organizational methods. In the dissertation work, the main bias is made on automatic flow control in megacities.

Improvement and implementation of automatic traffic light control for managing traffic flows is a complex task and can be solved only as a result of well-thought-out scientific and theoretical studies and analysis of practice, including foreign experience, on intelligent transport systems.

The scientific novelty of this work is the analysis of traffic flows in particular, and the road transport system in general, the major cities of the Republic of Kazakhstan, as well as the identification of problems in this area, based on which solutions for unloading street-road networks were proposed.

The practical significance of the thesis work is that based on the analysis of traffic flows in the major cities of the Republic of Kazakhstan, and taking into account foreign experience, a proprietary model of an intelligent traffic light and an information platform for automatic regulation of the traffic light that can be used in the implementation of intellectual Transport systems in the Republic of Kazakhstan.

The aim of the work is to consider the problems of regulating traffic flows, to study the positive foreign experience in the introduction and operation of smart traffic lights, to conduct a comprehensive analysis of the road transport system in the cities of the Republic of Kazakhstan and to develop proposals for solving problems related to transport flows.

In this connection, in order to achieve this goal, the following tasks were set:

- To reveal the general characteristic of the transport stream;
- To study ways of regulating traffic flows;
- Consider the concept, functions and types of traffic lights;
- Examine existing intellectual transport systems and traffic control systems;

- To study the foreign experience of traffic lights with automatic control;
- Carry out an analysis of the road transport system in major cities of Kazakhstan;
- Identify problems in regulating traffic flows in the cities of Kazakhstan;
- To give suggestions on the improvement and implementation of intelligent transport systems;
- To develop a model of an intelligent traffic light and an information system for automatic regulation of the operation of a given traffic light.

The object of the study are transport systems, infrastructure and technology of the transition to the "Smart City" through the installation of the latest automated traffic control systems.

The subject of the study is the system of intelligent installations in the transport system of the city.

The methodological basis of the research was a set of general scientific and private scientific methods of cognition, including dialectical, system-structural, functional, comparative and experimental.

The normative basis of the research is the provisions of the Civil Code of the Republic of Kazakhstan, laws on road traffic and by-laws in the field of traffic regulation, as well as civil legislation of a number of foreign countries.

Theoretical basis of the research. To develop the theme of the thesis, the corresponding theoretical and popular science literature, scientific works, articles, including the work of foreign scientists, were studied.

The practical basis for writing a thesis consists of examples of the use of intelligent transport systems in Kazakhstan and abroad.

Methods of research. The tasks were solved using the following scientific methods: scientometric analysis and classification of ICT in the subject area of Smart Traffic Lights, information-analytical and statistical analysis, mathematical modeling, decision-making methods on location of installations based on statistical analysis and simulation of the transport network, prototyping Software and hardware system.

The reliability of scientific results is confirmed by the correspondence of theoretical calculations and the results of the development of the practical part, as well as a comparison of the results obtained in the scientific literature.

Personal contribution of the author. The main scientific results of theoretical and applied research, the conclusions set forth in the thesis, were obtained independently by the author.

In this paper, the author owns a significant part related to the formulation of problems, the development of models and algorithms, as well as their software and hardware implementation and the conduct of experimental studies.

Realization of results.

The development of the hardware and software complex in the form of an intelligent urban terminal and the experimental approbation of the results was carried out on the basis of Arduino.

1. TRAFFIC LIGHT AS A BASIC MEANS OF REGULATION OF TRANSPORT FLOWS

1.1 Transport flows and ways of their regulation. Formation of ineffective states of traffic flows.

1.1.1 Traffic flow definition

A traffic flow is a collection of vehicles simultaneously participating in traffic on a certain section of a street-road network. The following main indicators are used to characterize traffic flows:

- Intensity of movement,
- Time interval,
- Density of motion,
- Speed.

In world literature, the very first and major monograph on the theory of transport flows is the work of S. Drew and R. Donald "Theory of transport flows and their management." It details the "driver-car-road" system elements and constructs traffic flow patterns, describes the process of formation and further functioning of the transport stream, its formalization and description on the basis of mathematical models, examines methods for regulating traffic on complex road junctions and highways and Design high-performance transport systems with high throughput.

Considerable attention is paid to the system approach to transport problems, as well as the methods of probability theory, mathematical statistics and queuing theory that are important for applications. Of great interest is the so-called deterministic approach to transport problems and the method of physical analogies.

The intensity of traffic of vehicles is the number of vehicles passing through the cross-section of the road in a certain direction or directions per unit of time: $N_a = n_a / t$

Distinguish specific and resulted intensity of movement:

1. The specific intensity of the traffic is the intensity level along one lane of the road.
2. The resulted intensity of movement is a set of intensity of movement of vehicles of different type with allowance for the corresponding reduced coefficients for these types. Since in a mixed flow of vehicles vehicles of different types occupy different road areas and have different dynamic characteristics, for the comparability of estimates, the number of vehicles of a certain type leads to a car with the help of the reduction factors.

It is the given intensity value that is used in the calculation of traffic flows and roads. The time interval (hour, day, year) for which the intensity of movement is determined depends on the purpose of the study. It should be taken into account that the traffic intensity is characterized by significant fluctuations both in time of day, in days of the week and in seasons, and in sections of the street-road network.

A sharp increase in motorization led to a change in the regularity of intensity fluctuations. Fluctuations in traffic intensity during the year are characterized by a coefficient of annual unevenness: $K_y = W_m / W_y$, where W_m and W_y are the monthly and annual traffic, respectively.

The coefficient K_y is used to calculate the annual volume of motion: $W_y = N_a D_m / (K_y K_d)$, where N_a is the measured traffic intensity, aut./h; D_m is the number of days in a month; K_d is the daily motion non-uniformity coefficient.

To distribute the traffic intensity by the days of the week, its maximum value is characteristic on Fridays, when the greatest number of individual owners uses the car. This intensity value should be taken as a calculation value.

During the day, as a rule, the greatest intensity of movement is observed in the morning rush hour, after it there is a small decline, after which the traffic intensity gradually increases until the evening peak hours, which are substantially longer in time than the morning one.

Transport is divided into three categories: public transport, non-public transport and personal or individual transport.

The composition of the traffic flow is characterized by the ratio of vehicles of various types in it. Assessment of the composition of the transport flow is carried out, mainly, by the percentage composition or proportion of vehicles of various types. This indicator has a significant impact on all traffic parameters. At the same time, the composition of the traffic flow largely reflects the overall composition of the fleet of vehicles in the region. The composition of the traffic flow affects the loading of roads, which is explained, first of all, by a significant difference in the overall dimensions of cars. If the length of domestic cars is 4-5 m, freight is 6-8, then the length of buses is 11, and the trains are 24 m.

The traffic flow consists of individual cars with different dynamic characteristics and controlled by different drivers, that is, it is not homogeneous.

In conditions of low-intensity traffic, when individual vehicles move along the road at large intervals, the driver in the choice of driving mode restricts the Rules of Traffic, the condition of the car and the road. In a dense traffic flow the driver is not free to choose the speed of movement, he can not always overtake and his behavior is largely determined by the overall rhythm of traffic on the road. Consequently, the intensive transport stream eliminates differences in the characteristics of individual drivers and machines.

Observations have shown that the movement of a dense traffic flow along a street or road is like the movement of water in a canal. If you quickly block the way to the flow of water in the channel, then it instantly stops and a reverse wave runs through the surface.

The reverse wave effect with respect to the transport stream is expressed in a sharp decrease in speed along the column and a reduction in the intervals between cars.

It is well known that a channel of a certain section can skip a certain amount of water per unit time. If we want to pass more water through the channel, we must increase its cross section. Something similar happens with the traffic flow moving along its canal - street or road. A part of a certain width can pass a certain number of cars, and if we want to increase its throughput, we must expand the road.

This analogy gave the specialists a reason to apply the laws of fluid motion to study the patterns of transport flows. Such a model, however, with certain limitations, makes it possible to carry out important studies and solve a number of practical questions on the regulation of motion.

The transport flow can be characterized by three main parameters: the intensity N, the average speed V, and the density D. These parameters are connected by the basic equation of the transport stream: N = DV.

As shown by observations, under favorable traffic conditions, an ordinary two-lane road with a width of the roadway of 7 to 7.5 m can skip no more than 2000 cars per hour. The maximum intensity is achieved at a speed of about 50-60 km / h. (Lobanov E. M. , Silyanov V. V. , etc. Capacity of highways).

One of the characteristics of the movement is the freedom of overtaking in the traffic flow. The need for overtaking appears due to the heterogeneity of the composition of the stream - cars and high-speed cargoes tend to overtake slowly moving vehicles to maintain the desired speed. With the increase in traffic intensity, the need for overtaking grows, and the opportunities for their implementation decrease, because in the oncoming traffic there are fewer and fewer intervals that provide safe maneuvering conditions. Observations show that overtaking runs freely when in the oncoming flow the interval between cars has a value that can be overcome in 20 seconds or more. If this interval is less than 7 seconds, then overtaking becomes almost impossible. Of course, some experienced drivers, driving a car with good dynamic qualities, can overtake and at smaller intervals, but this is associated with greater risk.

Table 1 The distribution of the number of intervals of different duration in the transport stream for different traffic intensities

Intensity of movement, auto / h	Number of intervals, %		
	Up to 10 s	From 10 s to 20 s	More than 20 s
100	8	22	70
300	22	44	34
500	34	49	17
700	44	48	8
900	53	43	4

Table 1 shows the data characterizing the possibility of overtaking on an ordinary road with a width of 7 - 7.5 m at different traffic intensities. Calculations show that at a traffic intensity of 100 auto / h in the transport stream, 70% of all intervals are greater than 20 s, and therefore overtaking can occur relatively freely. At an intensity of 900 auto / h of such intervals, only 4% remains, and this greatly complicates the overtaking conditions. Observations carried out by the Moscow Automobile and Road Institute show that overtaking is almost not performed when the total traffic on the road in both directions reaches 1500 1800 auto / h. This is due to the reduction in the transport flow of safe overtaking intervals.

1.1.2 Characteristics of traffic flow regimes

The movement of the traffic flow is an unsteady process in which the vehicle speeds vary widely under the influence of the magnitude and variations in traffic intensity, changes in road conditions, the composition of the traffic flow, weather factors, the condition of the cover, and the drivers' perception of traffic conditions.

Therefore, the mode of traffic flow is most often characterized by average statistical indicators, such as: average speed and average traffic density, average length and time intervals between moving cars, average overtaking depending on road conditions, intensity and composition of traffic, E. However, with a small traffic intensity along the road, the driving speeds of individual cars vary over a wide range, and therefore, in addition to the named characteristics of the traffic flow, 15, 50 and 85% traffic speeds are set for free traffic. The speed of 15% -security characterizes the mode of movement of slow cars, the speed of 50% -supply corresponds to the average speed of the transport stream, and the speed of 85% -security is the speed of fast moving cars. With a low traffic intensity in the traffic flow with vehicles that are dissimilar in terms of dynamic properties, the speed distribution curve of the number of cars has several vertices that characterize each group of cars. The cumulative curve (the supply curve) shows how fast the slowest cars move (up to 15% -security), the fastest cars (up to 85% -security) and what is the average speed of the traffic flow (at 50% availability). Overtaking in the free flow (with low traffic intensity) occurs frequently, which increases the number of accidents, as a result of collisions. The low-intensity transport stream best describes the stochastic (probabilistic) theories of the transport stream, including simulated computer simulations. Stochastic (probabilistic) theories of the transport flow include queuing theory, risk theory, game theory, Markov chains, and others.

The higher the traffic intensity (the denser the traffic flow), the less is the difference in the speeds of the individual cars and the less frequent overtaking - due to the small intervals between cars in the oncoming traffic.

In a homogeneous flow of high intensity, the distribution curves of the number of cars in terms of the speed of motion have a bell-shaped outline, characteristic of the normal distribution law. The average speed in a dense transport stream is the main characteristic of the driving mode. The rates of 15 and 85% security differ little from the average speed of the traffic flow, as a continuous flow of cars is formed, the average speed of which is significantly reduced compared to the average speed of a free and partially connected transport stream. The flow of high-intensity cars best describes the dynamic models of traffic flow. Dynamic (deterministic) theories of the transport flow include microscopic and macroscopic theories of dense flow.

Effective management of traffic flows on the network is carried out through a traffic management system, which is a complex of integrated solutions for all types of transport problems based on high technology, modeling of transport processes, software, and the organization of information flows in real time [1]. Efficiency is ensured by an adequate response of the system, system intelligence, to changes in the characteristics of traffic. It is clear that the construction of such an intelligent traffic management system is a complex, complex task based on the development and use of road traffic models, which assess and forecast the state of the traffic flow.

Real-time traffic flow management is the implementation of an optimal control strategy for the current state of the transport stream based on progressive methods for optimizing the operating mode of control vehicles for road traffic management.

To date, there is a specialized software for modeling traffic, optimizing the mode of operation of technical means of traffic management, etc., which can be used to build a traffic management system in real time. The problem is to ensure the development, in real time, of an adequate strategy for managing the current state of the transport stream. Technical systems for monitoring traffic flows provide the ability to obtain estimates of the characteristics of traffic flows to fix a particular state of the flow. However, since many traffic flow conditions are uncountable, it is necessary to develop a system of criteria for classification of transport states, with the subsequent definition of a flow control strategy for a particular class based on existing models of traffic flow optimization on the network.

When developing a system of criteria for the classification of transport stream states, it is necessary to take into account the problem of contradictions, on the one hand, due to the need to comprehensively take into account the characteristics of traffic flows, which entails a recognition error, and on the other hand, the need to reduce the dimensionality of the space of these characteristics, which deprives a sufficient degree of objectivity The process under consideration. The complexity of transport state identification in this case lies in the fact that the structure of the characteristics of traffic flows is probabilistic and the areas of membership criteria for different classes overlap. In this regard, the probability of an error in assigning a transport situation to the desired class is high, a probability that can only be minimized.

It is proposed to develop a neuro-fuzzy classification of transport conditions (SCTC), on the basis of which the system of generating optimal strategies for managing traffic flows on the network (SGOS), which is the basis for fuzzy rules for managing the transport situation, is already being built. Neuro-fuzzy systems have many advantages, but the deterrent is the length of filling them with knowledge (building the rule base) in the iterative learning process, which is carried out with the help of modeling and traffic optimization programs.

The SCTC system is developed for nodes (transport network) of various configurations, and then the SGOS system implements the coordinated management of the transport network. Development is proposed to be carried out on the basis of a universal method of constructing a base of fuzzy rules based on numerical data [3]. Advantages of this method are its high efficiency. In addition, it allows to combine the numerical information presented in the form of training data with linguistic information having the form of a rule base, by adding the existing database to rules created on the basis of numerical data. Specificity of the development applied to the transport network in this case is manifested both in the method of forming the initial data and in the construction of special functions used in the classification procedure.

A generalized scheme for managing traffic flows in a node (with an input number of not more than four) of a transport network is represented by a sequence of steps:

Detecting the characteristics of traffic flows of a direction
k ($k=\overline{1,4}$)
On the i-th lane
($i=\overline{1,p}$): traffic intensity $x_i(k)$, speed of the movement $v_i(k)$.

1. Determination $v(k)$ - of the average speed of the direction k.

2. Verification of the condition $v(1) \vee v(2) \vee v(3) \vee v(4)<10$,under which the state of saturation of the transport stream is ascertained and the strategy for managing the transport flows of the expert system is generated [2]; Otherwise, the ownership of the transport state is determined for a certain class, for which the management strategy is generated from the developed base of fuzzy control rules.

The basis for the classification rules for transport states is created for a system with two inputs and one output, as follows:

Define $x(k)=\sum_{i=1}^{p} x_i(k)$ ($k=\overline{1,4}$),

For $x_1 = \max\{x(1), x(3)\}$, $x_2 = \max\{x(2), x(4)\}$

We find domains of definition $X_1 X_2$, that we divide into $2N + 1$ regions (segments), the value being chosen individually, and the segments can have the same or different length. We construct the membership functions for a certain class of transport states, it is proposed to use the density function of the normal distribution by the principle: the top of the graph is located in the center of the partition region, the branches of the graph lie in the centers of the neighboring regions.

The degree of data $x_1 x_2$ belonging to certain classes will be expressed by the value of membership functions. Then, for each pair $x_1 x_2$, the rule of conformity to the transport state class is determined (by the researcher). Since there is a large number of pairs, there is a high probability that some of the rules will be contradictory. This applies to rules with the same premise (condition), but with different consequences (conclusions). One of the methods for solving this problem is to assign each rule a so-called degree of truth with a subsequent choice of conflicting rules for the one with which this degree is greatest, after which the rules base is filled with qualitative information. To determine the quantitative value of the parameters of the optimal control strategy for the data $x_1 x_2$, a defuzzification operation must be performed. Such a method is easy to generalize to the case of a fuzzy system with any number of inputs and outputs.

The considered principles of building the SCTS system were realized for the transport network of the central part of many large cities. To realize the optimal management of transport flows, key crossings of four types were identified depending on the configuration of the permitted traffic directions:

The first type of intersection is the direction of the movement "north-south", "south-north" in three bands directly and to the right, the direction "west-east", "east-west" in two lanes right and right;

The second type of intersection is the direction of movement only "north-south", or "south-north" along one strip directly, to the right and to the left, the direction "west-east", "east-west" in two lanes directly and to the right in the direction Cross flow motion;

The third type of intersection is the direction of the "north-south" movement in three bands directly, "south-north" in three bands right and right, the direction "west-east" along one strip directly and to the right, "east-west" one by one A strip to the right and to the left;

The 4th type of intersection is the direction of the "north-south" movement in three bands directly, "south-north" in three bands directly and to the right, the direction "west-east" along one strip directly and to the right, "east-west" Lane to the right and to the left.

The following functions $\mu_j(x), j = \overline{1,3}$ have been developed intensity of motion, auto / h:

- $\mu_1(x) = e^{-\frac{(x-a_i)^2}{800}}$, $a_i = 100i, i = \overline{1,6}$ one strip of the partition region $X_1 = [0; 600]$;
- $\mu_2(x) = e^{-\frac{(x-a_i)^2}{1800}}$, $a_i = 100i, i = \overline{2,14}$ on two bands of the partition domain $X_2 = [0; 1500]$;
- $\mu_3(x) = e^{-\frac{(x-a_i)^2}{5000}}$, $a_i = 100i, i = \overline{3,19}$ on three bands of the partition domain $X_3 = [0; 2000]$;

As a criterion for the classification of the transport state, traffic delay is used. Based on the results of modeling the traffic flow at the intersections of the indicated types, regression models of the criterion for estimating the state of the transport stream, motion delays were developed:

$z_1 = -0{,}43 + 0{,}0005N_1 + 0{,}0002N_2$ at the intersection of type 1 (Figure 1);

$z_2 = -0{,}30 + 0{,}0004N_1 + 0{,}0006N_2$ at the intersection of type 2 (Figure 2);

$z_3 = -0{,}49 + 0{,}0005N_1 + 0{,}0001N_2$ at the intersection of 3,4 types (Figure 3), where $N_1 = x_1(k), N_2 = x_2(k)$ - maximum intensity of cross directions of motion.

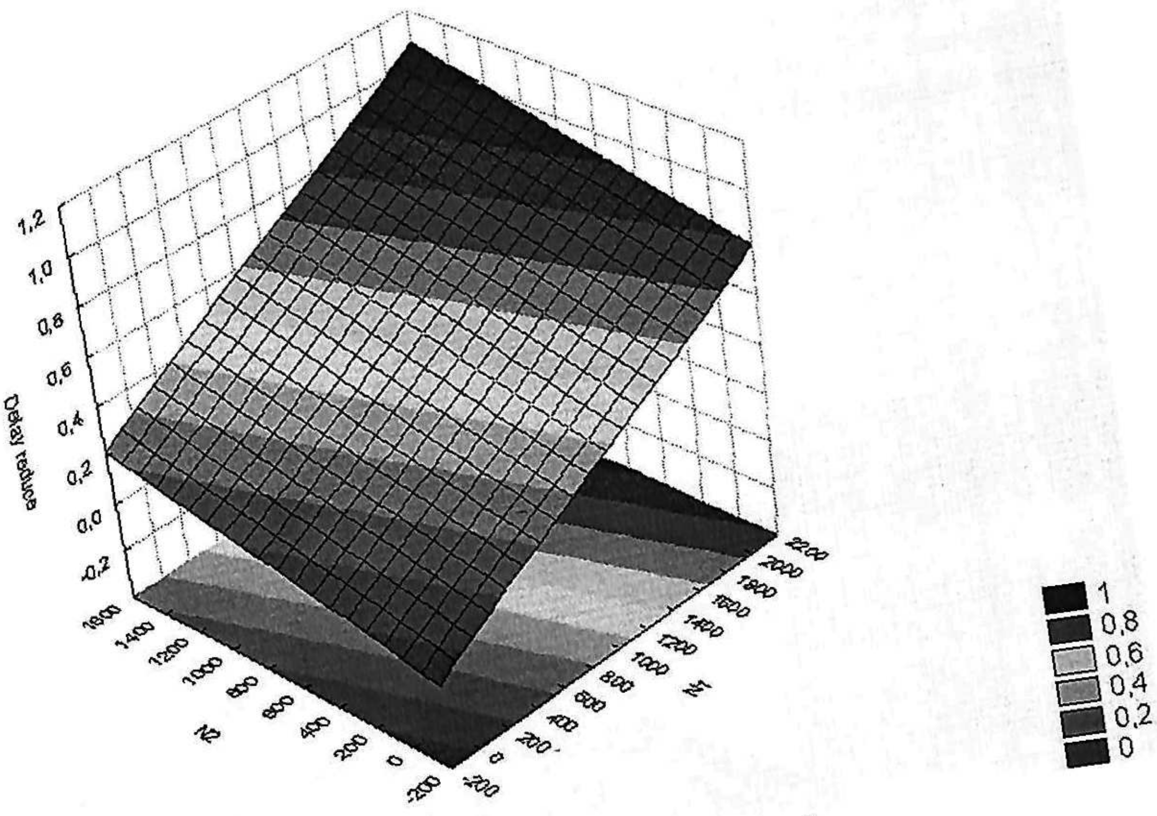

Figure 1 Changing traffic delays at the intersection type 1

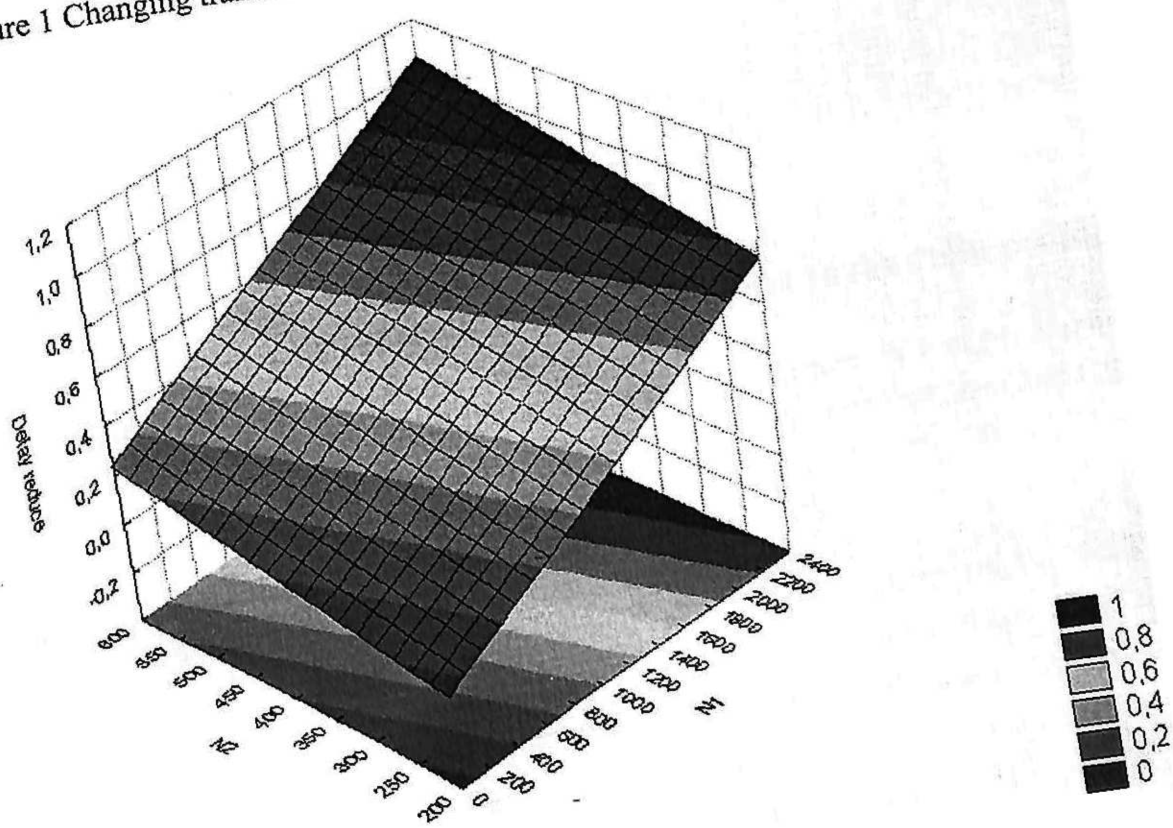

Figure 2 Change in motion delay at the intersection of type 2

According to the developed models of delay estimation after the correction procedure by means of correction factors, the state of the transport stream is determined. The basis for the rules for the identification of transport states constructed in this way is the basis for the design of the GSR system for managing traffic flows on the network.

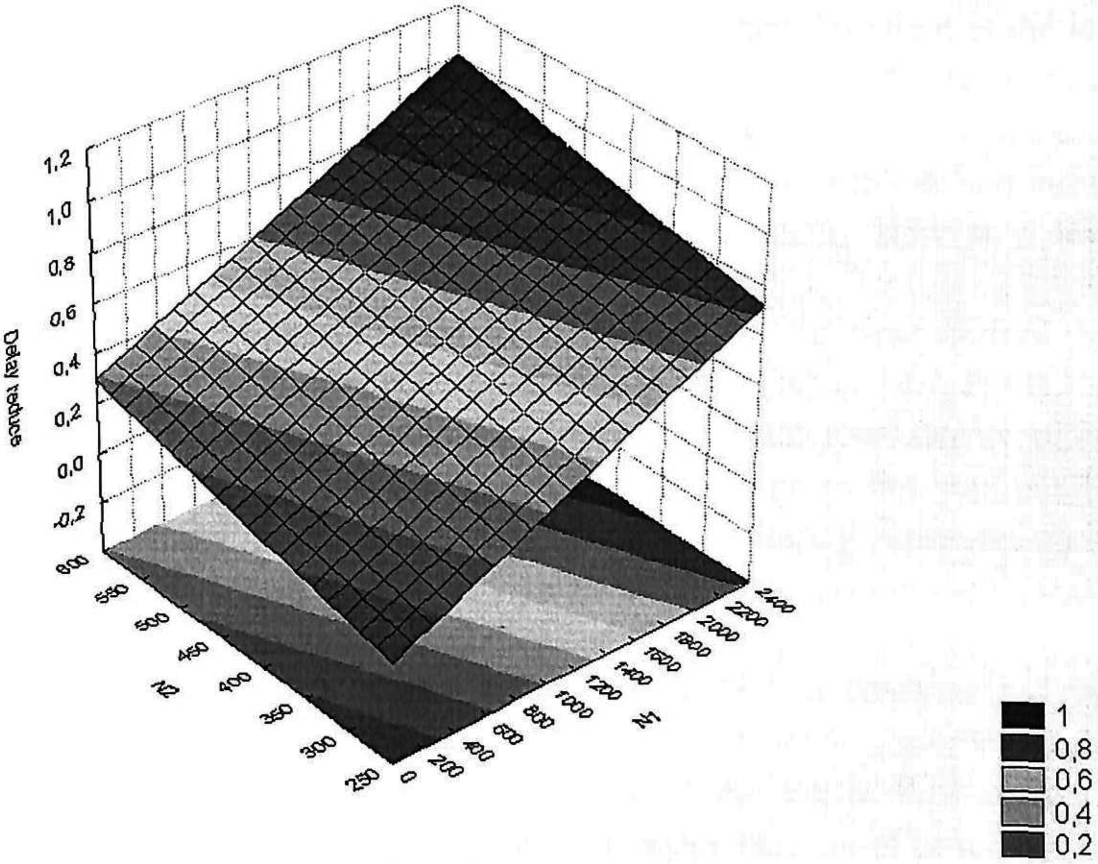

Figure 3 Change in motion delay at the intersection of type 3.4

1.1.3 Ineffective state of traffic flows. Congestion as the main problem of limited traffic flow

The ineffectiveness of the state of the transport stream is a characteristic of the traffic in which the traffic flow is restricted in free movement on the road network segment. There are categories of the level of traffic flow convenience, which are determined by the values of the coefficients z, c, p (>=0,1 – <=1) .

Level categories of driving comfort:

1. The level of motion convenience "A" is characterized by the following values of the coefficients: z <= 0.2; C> = 0.9; P <0.1. Overtaking is almost non-existent, cars do not interact with each other. The driver can maintain the desired speed. Decrease in average speeds is insignificant. Emotional tension of the driver is low. Drivers and passengers do not feel uncomfortable when driving a car. Trips are comfortable. The transport flow at a level of convenience of motion A is called free.

2. The level of the convenience of movement "B" is characterized by the following values of the coefficients: z = 0.2 ... 0.45; C = 0.7 ... 0.9; P = 0.1 ... 0.3. In the flow, the number of cars that overtake or are forced to move in packs behind slowly moving cars is continuously increasing. A sharp drop in the average speed of movement is observed. Studies using a running laboratory show the impossibility of overtaking at z = 0.45. This value can be considered the upper limit of the level of convenience of motion B. Emotional tension of drivers quickly increases as the traffic load and approaches the largest. The frequency of maneuvers is the greatest. At this level of driving comfort, drivers experience a decrease in ride comfort due to the need for overtaking or detour maneuvers. The traffic flow at a level of convenience of movement "B" is called stable.

1. The level of convenience of movement "C" is characterized by the following values of the coefficients: z = 0.45 ... 0.7; C = 0.55 ... 0.7; P = 0.3 ... 0.7. There is a further reduction in the speed of movement. Emotional tension of drivers reaches the highest level. Drivers are uncomfortable due to the impossibility of overtaking slow-moving cars and the need for close monitoring of the vehicle ahead. The comfort of the trip is dramatically reduced. The transport stream consists of separate large groups and packets and is called unstable.

2. The level of convenience of movement "C" is characterized by the following values of the coefficients: z = 0,7 ... 1; C = 0.55 ... 0.4; P = 0,7 ... 1. Movement occurs with stops due to the state of the traffic flow close to the congestion. Emotional tension of the driver is reduced because of lower speeds and movement with constant low speeds. The speeds of all cars are close to each other, the standard deviation of the values of the speeds is small. Drivers and passengers are most uncomfortable with the trip. Movement occurs with uneconomical speeds in column mode. Traffic flow at a level of convenience of movement "G" is called saturated.

One of the main reasons for the ineffective state of the traffic flow is congestion, formed at a low level of traffic convenience. Traffic experts say that if within one or three cycles of traffic regulation the driver of the vehicle can move through the intersection in any direction, then this situation can not be called a zamorovoj. And if the traffic light cycle is 90 seconds and the driver needs to wait for his turn on the road through the intersection of 3 -5 cycles, this phenomenon can be called pre-departure. Being in front of the intersection for more than 7.5 minutes, the driver is in a harsh situation. In the expert dictionary - auto technology, the concept of congestion is interpreted as a delay in the movement of vehicles, caused by a significant decrease in the capacity of the MAC section. The congestion occurs at a time when the intensity of arriving vehicles on this section of the road exceeds the capacity of this section. Low throughput, congestion can occur due to the peculiarities of the geometry of the road network or nodal parts; Incorrectly modeled traffic control system; Unregulated junctions; The system of regulation of traffic lights in an unchangeable mode, without taking into account peak hours and night time, when the flow rate can be regulated only by signs of traffic, and the traffic lights form an extra simple car on a free roadway.

1.1.4 Methods for regulating traffic flows

The description of methods and methods of managing transport flows was first described by S. Drew and R. Donald in the work "Theory of transport flows and their management." In this monograph, among other issues, methods for regulating traffic on complex road junctions and highways and designing high-performance transport systems with high throughput are considered.

In other words, the system for regulating traffic flows is designed to address the actual task of managing traffic at busy intersections in conditions of maximum traffic congestion by vehicles. Due to continuous automated traffic monitoring, operational situation analysis, forecasting and prevention of possible traffic congestion, pre-emergency and emergency situations, the problem of regulating transport flows, including the increase in the throughput of intersections, is solved.

The methods of regulating transport flows in large cities, in the most general interpretation, can be divided into two classes: infrastructure and organizational. The first class includes those methods that are associated with the construction of additional infrastructure capacity: the laying of new roads, the construction of interchanges, bridges and tunnels. The second class includes methods related specifically to organizational solutions in transport: the allocation of trunk streets, streets with unilateral and asymmetric traffic on the street-road network, the introduction of information systems, the allocation on the existing roads of lanes for public transport, the improvement of the work of intellectual traffic lights, P. Most often, with other things being equal, infrastructure methods are much more expensive than organizational methods.

Organizational ways of regulating traffic flows also include:

- road controllers;
- transport detectors;
- traffic lights at the intersection;
- means of communication.

From the point of view of the system approach, the above methods of organization and methods of traffic management can be divided into methods that operate in real time (on-line methods) and outside it (off-line methods).

The first group includes manual control, as well as algorithms for automated control based on obtaining information from transport detectors. Based on on-line methods, the development of adaptive motion control systems (Adaptivecontrolsystem), which uses data in "real time" and automatically change the duration of the response time in response to the changing state of traffic flows. In some cases, adaptive systems can automatically, over time, determine the best modes of operation of traffic lights, including in conditions of irregular traffic. In other words, adaptive systems are self-learning. However, it should be noted that the process of "self-study" can be lengthy. In addition, in conditions of overloaded traffic, the adaptive system of traffic management and organization is usually ineffective, since, on the one hand, there is an unsolvable conflict of transport requests, and on the other hand, a qualitative solution to the optimization task inside the cycle is impossible because of the lack of time for implementation Serious calculation. Therefore, at present, most adaptive systems work "from optimal initial plans", subject to change within the cycle only within limited limits.

The main competitive advantage of methods based on ideas of an organizational nature within the existing infrastructure, as mentioned above, is its low capital intensity. Let us consider in more detail each of these methods.

The method of redistribution of traffic flows consists in calculating the matrices of motor transport correspondence and in the subsequent distribution and redistribution of traffic flows, namely, how to distribute existing traffic flows - between city districts - on the existing transport network. This method consists of two stages. The first is the formation of correspondence matrices. The second is the calculation of the optimal routes for the redistribution of flows and the conduct of organizational arrangements. At the same time, the first stage is realized using the existing equipment - video cameras (that is, it does not require significant costs for its implementation), the second stage is performed by means of mathematical and simulation modeling, the experience of which is available in research and design organizations of the city.

When regulating traffic flows at an intersection with the help of transport detectors, the vehicle queue lengths (density) and the dynamics of filling the carriageway with vehicles on all directions of the intersection are identified. The data from the detectors are transmitted along the communication lines to the road controller and are processed there by means of adaptive phase control algorithms of the intersection control cycle. In this case, the duration of switching on the green signal of traffic lights increases in the direction where the vehicle queues are longer.

Manual control is carried out by the road controller, which collects information from the transport detectors about the current state of the intersection (traffic congestion in vehicles), decides on the organization of the sequence of the phases of the intersection control cycle in the autonomous operation mode, and controls the traffic of the intersection traffic lights.

The transport detector operates as a radar with a zone of responsibility on one or more lanes of the road. Information about the availability of vehicles on the communication lines is transmitted to the road controller.

Adaptive intersection control algorithms are tuned to a specific intersection, given the geometric features of the terrain, the value of the intersection on the highways. The corresponding software is implemented in the system unit of the road controller.

Algorithms that operate outside real time are subdivided into methods that allow changing control parameters in the daily or calendar control cycle, and methods that provide a single setting of such parameters for a long period of time.

These are all algorithms of traffic light regulation, working in the calendar automation mode.

In the group of off-line algorithms, the organization and management of traffic can be applied at the information gathering stage to monitor traffic flows, the decision-making stage (when calculating control parameters and choosing the period of their action), and at the stage of adjusting the control parameters to the technical means of regulation.

The controlled object in the systems of organizing and coordinating the movement is the traffic flow. The main features of traffic management:

- non-stationarity by time of day, by day, by month, by seasons of the year, by years;
- Stochasticity, that is, their characteristics allow forecast only with a certain degree of probability. In general, the current value of the transport stream characteristic can be considered as a combination of a deterministic and a probabilistic component;
- incomplete controllability, the essence of which is that even in the presence of the control system of complete information on traffic flows and the possibility of bringing control actions to each driver, these impacts can in principle only be of a recommendatory nature in a number of cases. Thus, we can talk about the fundamental impossibility of achieving 100% of the effectiveness of the control action.

In accordance with the features of objects and organizational methods used above, the management of transport flows can be carried out using the following methods:

1. central adaptive management, where the organization and coordination of the movement is completely shifted to the central system, and the impact is formed in on-line mode:

2. recalculate the coordination of plans made in real time,

3. use of libraries of time plans calculated in advance;

4. local adaptive control, implying self-regulation of traffic on a local level using intelligent controllers with predefined cycle parameters, or with gradually adjustable cycle parameters;

5. local time management of traffic, in which the selection of plans is made from the library of plans, calculated in advance using various optimization programs;

6. combined control, in which co-ordination of control takes place from the central station and from the local controller, with the main priority being given to both the central station and the local controller, at the user's choice.

7. operative management - manipulation of transport streams in the event of any planned (unplanned) event, for example, march, sporting event, etc.

Let's consider a way of regulation of transport streams by means of intellectual transport systems. A systematic approach to solving problems of managing the transport infrastructure of a large city is provided by the development and use of intelligent transport systems.

Methods of automated control of traffic flows by means of traffic signaling (traffic signal regulation) on city street-road networks allow classification according to the spatial and temporal criteria.

According to the spatial criterion, all algorithms of traffic regulation are divided into local and coordinated.

The traffic light control algorithm is local if only information about the traffic flow on the approaches to this intersection and in the intersection zone is used to determine the control parameters at the intersection.

The local control algorithm provides for the use of information obtained both directly on the stop lines and at remote approaches to the intersection (200-400 m from the stop line). Local algorithms define the control cycle, the sequence of control phases, their duration or phase switching points, and the parameters of intermediate cycles. To determine the above parameters, information is used on the geometric characteristics of the intersection, the intensity and composition of traffic flows on approaches to it and / or on the geometric directions of passage through the intersection, the presence and / or absence of transport and pedestrians in different intersection areas (on stop lines, in conflict zones Points).

A feature of coordinated algorithms is the use of information on the transport situation at several crossroads, usually connected to a single network, which is characterized by a significant traffic flow between adjacent intersections and small (up to 600-700 m) distances between them, to determine the regulatory parameters. As a rule, at a coordinated level, regulation cycles are defined for the crossroads group and shifts. To determine these parameters, in addition to the data needed for local control, information is used about the network topology, the relationships of traffic flows on adjacent stop lines and / or on geometric directions of passage through intersections, the times of passage between adjacent stop lines. The initial information used for coordinated management may include a matrix of correspondence and data on the routes for their implementation.

According to the time criterion, all algorithms of traffic regulation are divided into methods that implement traffic control according to the forecast and methods that operate in real time (adaptive algorithms). At the same time, algorithms using the short-term forecast of the transport situation for the next 3 to 15 minutes are traditionally applied to adaptive methods. Management of the forecast (or hard management) does not exclude a sufficiently frequent (up to 3-5 times in the daily cycle) changes in the regulatory parameters, but these parameters are determined not based on the current transport situation, but by the method of forecasting based on the earlier performed (for a day, Week or longer period) observations. Intermediate position between adaptive and non-adaptive algorithms is occupied by methods based on situational management. The methods of this group assume a preliminary calculation of the control parameters for different classes of transport situations and the creation of a library of typical control regimes. The choice of a specific mode from the library is made in real time on the basis of current information about the transport situation and referring it to one of the classes of transport situations.

Summing up the aforesaid, the most capital-intensive and effective way to solve problems in regulating traffic flows, in our view, is the development and use of intelligent transport systems. Within the framework of this system, it is necessary to focus on traffic light regulation, namely, the improvement of the work of intelligent traffic lights.

1.2 Definition and history of traffic lights

1.2.1 Definition, functions and types of traffic lights

The issue of creating a vehicle that helps and facilitates the regulation of the movement of vehicles arose in the middle of the 19th century.

This problem arose in connection with the fact that there was a time when crossing the street of a big city was not easy, and sometimes, and dangerous for life. People stood on the sidewalk for a long time and waited for the endless stream of horse-drawn carriages to end. The most impatient ran across the street, at the risk of falling under the hooves of horses or carts of wagons.

In the modern world, where the movement of machines is carried out in several rows, there are many intersections and junctions on the roads, the need to cross the road to pedestrians or to drive cars moving in the transverse direction is very acute. In this connection, it is impossible to imagine the movement of vehicles and pedestrians without this well-known invention of humanity - a traffic light.

A traffic light (in Greek meaning "light carrier") is an optical device that regulates traffic with the help of light signals. Traffic lights regulate the movement of road, rail, water and other transport, as well as pedestrians at pedestrian crossings.

The history of the appearance of a traffic light, and, accordingly, of a smart traffic light, can be divided into 4 stages.

I stage - mechanical regulation

Regulation of motion with a mechanical device began more than 140 years ago, namely in London, near the building of the British Parliament. He was invented by J.P. Knight (English J.P. Knight) - a specialist in railway semaphores. The first traffic light stood in the center of the city on a pole 6 meters high near the building of the British Parliament. Managed it manually, specially assigned person. This traffic light had two semaphore arrows: raised horizontally signified the signal "stop", and lowered at an angle of 45 ° - movement with caution. In the dark, the gas lantern was illuminated, with the help of which the signals of red and green colors were fed. The traffic light was used to facilitate the passage of pedestrians across the street, and its signals were intended for vehicles - while pedestrians are on, vehicles must stand. At the beginning of 1869 the device's lantern exploded and wounded the policeman, who supervised the traffic lights. After this incident, the traffic lights were forgotten almost for 50 years.

II stage - automatic control

The first automatic traffic lights system, capable of switching without direct human intervention, was developed and patented in 1910 by Earnest Sirrine from Chicago. His traffic light used non-illuminated inscriptions "Stop" and "Proceed".

Stage III - automatic control

The inventor of the first electric light is Lester Wire from Salt Lake City (Utah, USA). In 1912, he developed, but did not patented, a traffic light with two round electrical signals (red and green).

James Hog's traffic light system (pictured above) August 5, 1914 in Cleveland, Ohio, USA The American Traffic Signal Company installed 105 electric and electric trains on the intersection of 105 streets and Avenue Euclid).

They had a red and green signal and, switching, sounded a beep. The system was controlled by a policeman sitting in a glass box at a crossroads. Traffic lights set the rules of motion, similar to those adopted in modern America: the turn to the right was carried out at any time in the absence of interference, and the turn to the left - to a green signal around the center of the intersection.

In 1920, tri-color traffic signals using a yellow signal were installed in Detroit (Michigan, USA) and New York. The authors of the inventions were William Potts and John F. Harriss, respectively.

In Europe, similar traffic lights were installed in Paris in 1922 at the intersection of the Rue de Rivoli and Sevastopol Boulevard (the French Boulevard de Sebastorel) and in Hamburg in the Stephansplatz square. In England - in 1927 in the city of Wolvehampton (English Wolverhampton).

Modern traffic lights are complex devices that consist of a traffic signal controller, a traffic light, vehicle sensors, poles and pillars of traffic lights. The computer in the controller controls the selection and synchronization of the directions of movements in accordance with changing driving conditions, which are registered by the sensors to indicate the passage or presence of vehicles.

The management of the traffic lights is automated and is carried out from a remote control panel (VPU). In modern large cities, sophisticated automated traffic management systems (ASDS) have been introduced to regulate traffic.

In connection with the history of the traffic light, the name of the African-American inventor Garrett Morgan (Garrett Morgan), who patented the original traffic light in 1922, is often mentioned. There is a persistent myth about the great influence of Morgan on the development of traffic lights, but in reality he is only one of many inventors of various traffic lights of the early XX century.

What does each of the traffic light signals mean? Why are these three colors chosen?

Red color is more noticeable, it can not be confused with any other. That is why most road signs are surrounded by a red border, and fire trucks are painted with red paint. Red color is conspicuous, with him we have ideas about fire, danger.

Red color holds us back, calls for caution. That is why the red signal of the traffic light was instructed to stop the transport and pedestrians.

The yellow color reminds us of the sun, it can be a friend or an enemy (if it overheats). Sunny, as if warns: "Attention! Be careful, do not rush. "

Green color: green fields, forests, meadows. In a word, everything related to us with rest and rest is security.

1.2.2. Stages of the evolution of traffic lights. The reasons for changing the mechanisms of their functioning

On the streets of our cities and on highways, electronic displays, signs of variable information, various sensors and video cameras began to appear more often. Traffic lights are rapidly "getting smarter," and every self-respecting city seeks to organize a "traffic control center". Demand creates supply, and some companies are beginning to develop a new direction for them - automating traffic.

How did the evolution of control devices occur?

The main types of "smart" traffic lights are interesting to consider in the historical perspective, as they did not immediately appear and evolved from simple to complex.

Automobile traffic lights came to us from the railwaymen. The first electric traffic light with manual control in the United States was installed in Cleveland in 1914. And in three years, in 1917 in Salt Lake City, a system was created that controls traffic lights at six intersections. The role of the road controller was performed by the regulator. In 1922, Houston did the same, but at twelve crossroads. The control was carried out in manual mode from a special tower.

The concept of automatic traffic lights was proposed in 1928. It could install and set up any electrician and everyone started to buy and install such traffic lights. But immediately there were problems in big cities, where there are morning and evening peak hours, in which it would be good to change coordination plans for traffic lights, so as not to create traffic jams. In full growth there were problems of shortage of the personnel for this responsible business. An inquisitive American mind pondered the further development of road automation.

In the period from 1928 to 1930, the inventors proposed various designs of pressure detectors that determine the presence of cars at an intersection. This made it possible to make the first models of traffic-reactive traffic lights. Such traffic lights had an effect on highways, where the red on the main turn was switched on only if a car drove up from the side of the secondary road. Such systems are still in the US and are doing their job well at isolated intersections. Similarly, pedestrian call buttons work, and when pressed, the pedestrian phase is built into the next regulation cycle. In 1952, Denver installed the first analog controller, which allowed uniting several scattered intersections into a single managed network and switching pre-calculated coordination plans depending on the time of day and days of the week. In the next decade, several hundred such systems were installed around the world.

Such systems actively used the bias parameter, including green not immediately at all intersections, but with a shift that depends on the distance between intersections and transport parameters ("green wave"). A specially trained engineer calculated and drew on the paper the coordination schemes, which were then laid in the controllers. The system was so simple and reliable that it is actively used so far in cities not burdened with excessive traffic.

In 1960, in Toronto, for the management of traffic lights, the first "real" computer was installed - a chic unit IBM 650 with drum memory for 2000 machine words. This was a huge breakthrough in traffic management technologies! Three years later, under centralized control, there were more than 20 intersections, and by 1973 the computer was already controlling 885 crossroads!

Seeing such an obvious success, IBM continued to work on using its computers in the management of traffic lights. In 1964, he launched a project in the center of San Jose with an IBM 1710 computer, and in 1965 IBM 1800 (an advanced version of the 1130 model with an increased number of I / O ports) was installed for the city of Wichita Falls (Texas), which successfully ran 85 intersections. The computer in San Jose was also replaced later by IBM 1800. The system was so successful that this configuration was used in many American cities from Austin and Portland to New York.

Work on the standardization of traffic light control systems started in 1967. In the framework of the pilot project, a control system for Washington was built, which included 113 intersections equipped with 512 transport detectors based on an inductive loop. The computer was able not only to blindly switch coordination plans, but also to obtain information about traffic queues at intersections (then Doppler radars for measuring the flow rate were not used).

The critical mass of traffic lights connected to computers was achieved, and the transition from quantity to quality was only a matter of time. Large-scale research in the field of developing control algorithms began. The idea to have coordination plans for all cases of life in theory was not bad, but for all cases of life, as it turned out, there is no plotting. The development of each plan in the 70's was done on paper and was quite a labor-consuming and creative process. And if for a long street with traffic lights, like Leninsky Prospect in Moscow, it was easy to calculate the algorithms, then on a network of streets it was already quite a trivial task. There's more that there are a lot of cities, and not all of them can afford to keep a competent transport engineer in the state.

And in the 1970s, the British Research Bureau TRRL (The Transport and Road Research Laboratory) developed and implemented in the streets of Glasgow the SCOOT (Split, Cycle and Offset Optimization Technique) system, which allowed "playing" parameters of the traffic light cycle within certain limits depending on From the information of transport detectors measuring the presence and length of queues at traffic lights. SCOOT combined the advantages of fixed coordination plans for the network and adaptive control when the "smart" traffic light itself "steers" the cycle and durations of green signals. SCOOT in the 80's had a number of successful deployments in Europe and North America. Moreover, now this algorithm (already in the third generation) is licensed to more than 100 companies for use in its systems.

SCOOT in the third generation shows the wonders of sophisticated management: it is able to handle unusual situations, to take away congestion, to smooth out the consequences of interference in the traffic flow of regulators and temporary overlaps of traffic, which they like to arrange in themselves know which country.

Simultaneously with SCOOT as mushrooms after the rain in the 70's and 80's began to appear similar control systems. The Australian system SCATS (Sydney Coordinated Adaptive Traffic System) became the main competitor of the British and was also widely introduced all over the world. Like SCOOT, SCATS refers to systems that are "responsive" to traffic (traffic responsive).

Also, fully adaptive control algorithms (traffic adaptive) were developed, which were represented in the world by OPAC (Optimized Policies for Adaptive Control) and RHODES, developed by the Arizona University.

Now the difference in management efficiency between adaptive and "sensitive" systems has practically become obliterated. Like the race for Internet browsers, these "buggers" and "spikers" are constantly doing research to prove the effectiveness of their algorithm, but reports of independent experts say that in general there is no particular difference.

But now with the development and cheapening of computer technology, there are opportunities to increase the survivability of control systems. Part of the control logic was sewn directly into the road controllers, which, even in the event of a break in communication with the center, were not lost and began to be combined into control clusters with neighboring controllers. In the conditions of territorially distributed control systems, disconnection of communication channels is common, and such a bonus has become absolutely not superfluous.

To date, projects are trying to solve the city's transport problems, which implies a more reasonable approach to design and achievement of quite practical and socially useful goals. And if earlier these projects were exclusively in the hands of builders, now they were attracted to system integrators and software developers.

Any automated control system receives information "from the fields" or from the operator, processes it and generates control actions. Accordingly, it is possible to divide everything that stands "in the fields" into two groups. The first group collects information, and the second group has an impact on transport flows.

Detectors of traffic flow

The task of the transport stream detectors is to collect the following information about the flow:

- Intensity (number of machines per time unit)
- average speed per interval
- the fullness of the lane or road (the percentage of road space occupied by vehicles)

The traffic flow detectors are equipped with two or three sensors of different types ("dual" and "triple" technologies). Thus, in the "triple" detectors, the microwave radar measures the speed, the ultrasonic detector provides an estimate of the dimensions and classification of the machines by class, and the multichannel infrared detector provides counting of machines, determination of intensity and employment.

Typically, the detector can monitor only one band. Therefore, place them on the support for several pieces at once, according to the number of strips. Accordingly, the intensities are summed up, and the rates and employment are averaged.

On the three listed indicators, you can determine the state of the flow at the "cross section", that is, in the area under the detectors. When the flow of machines rises, for example, during rush hour, then the intensity and speed first increase. Then the speed drops a little, and then comes what we call "cork". Cars go slowly and with stops, the intensity drops sharply, the speed too. And employment, on the contrary, increases sharply.

Figure 4 shows a picture from real detectors on a four-lane highway per day.

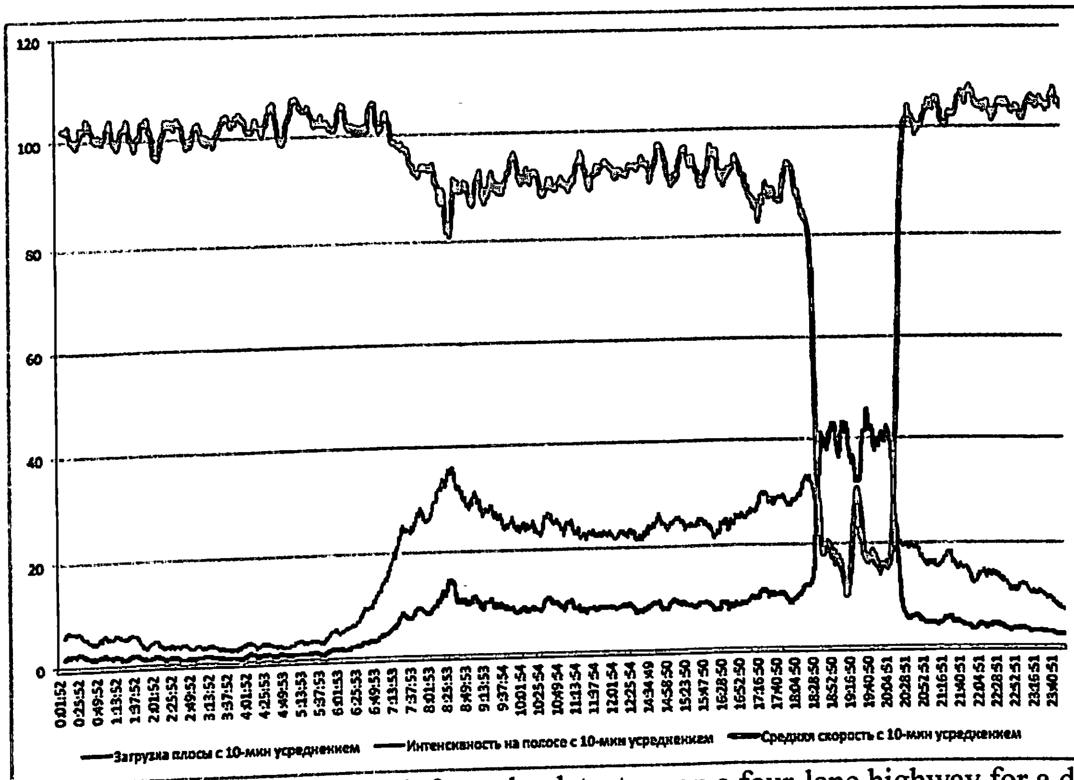

Figure 4 The image of the graph from the detectors on a four-lane highway for a day

With the naked eye you can see how in the evening rush hour there is a "traffic jam". In general, a simple science. If we add here the analysis of statistics for previous periods, we will get a complete system for collecting and initial processing of information on traffic flows.

Automatic road weather stations (ADMS)

On highways you can sometimes see high masts, on which an automatic weather station is installed. It collects information on weather conditions and the condition of the road surface. For example, information about the presence on the asphalt of "black ice", which on the highway can lead to bad consequences. The list of measured parameters can reach three dozen positions.

Weather stations periodically transmit information about weather conditions in the form of a text or XML file to interested parties. Weather information can affect the introduction of certain speed limits, as well as the launch of specific control scenarios in the "cataclysm" zone.

Video surveillance and automatic video analysis

As a rule, video surveillance is a separate subsystem and does not apply to managing software. But the fact that you can connect an analytical module to the video stream is very interesting. Because this makes it possible to automatically record all possible incidents in the field of visibility that the operator can overlook. For example, now there are systems that can identify accidents, unforeseen stopping of cars, dropped cargo, fire and traffic against the flow. All the way to cover these systems is meaningless, since it is quite expensive. But in the tunnels or mountain serpentines, the use of these systems is fully justified.

Automatic incident detection systems consist of fixed and properly "targeted" video cameras and analytical software that inform the operator or system of the place and type of a recorded incident.

Signs and scoreboard

Traffic management for motorists is expressed in their usual form - in the form of traffic signs, traffic lights and all sorts of information on electronic displays. Sometimes automatic gates are used (in parking lots, in tunnels and on toll roads). In the west, it is also customary to limit the access to motorways (On-ramp metering).

The signs and scoreboard of variable information are arrays of light-emitting diodes with a rather complex technical part. Since they are designed to work in outdoor conditions, they provide modes of heating, cooling, protection from condensation and from icing. They are able to control their condition (like all other road equipment) and are made of fairly durable material. Near the electronic road sign looks massive, LEDs are hidden inside the depressions in a strong grate. The sign should be well visible at a distance and at the same time should not glare in the sun.

Signs can display a fixed number of pictures, depending on the model. Electronic scoreboards also differ in various restrictions on fonts, the number of lines and the number of "pixels" horizontally. Some are able to display letters only in separate boxes, and some provide complete freedom within the framework of their "permission." The road controllers help to manage all this.

Road Controllers

Road controllers are ordinary computers in industrial design. They usually work on Linux software. In terms of functionality, they are significantly different from each other. A copy in the photo is able to collect telemetric information from traffic flow detectors and to light signs and a scoreboard on one support. As you can see in the photo, he has a contact LCD screen that allows the installer to configure the device in the field. Often, controllers are provided with interfaces for quick backup and recovery, which allows you to make settings in the office, and in conditions of bad weather on the support, only send the information to the controller in the near future, if this can not be done over the network (for example, in the case of using GPRS networks). Some controllers may contain additional control programs that allow them to act independently when the communication with the center is disconnected.

Interfaces and network protocols of the controllers are rigidly standardized, all documentation is open. While internal proprietary software and control algorithms are protected.

Historically, the separation of equipment into "mainline" and "urban".

In order to understand how control algorithms work, it is necessary to know the basic definitions of traffic signal regulation:

- Control cycle (Interval). The validity period of a specific combination of traffic signals
- The phase of regulation (Signal Phase). The totality of the main and the following intermediate measure
- The control cycle (Signal Cycle). Periodically recurring set of all phases
-

Figure 5 illustrates well the concept of cycle, phase and interval.

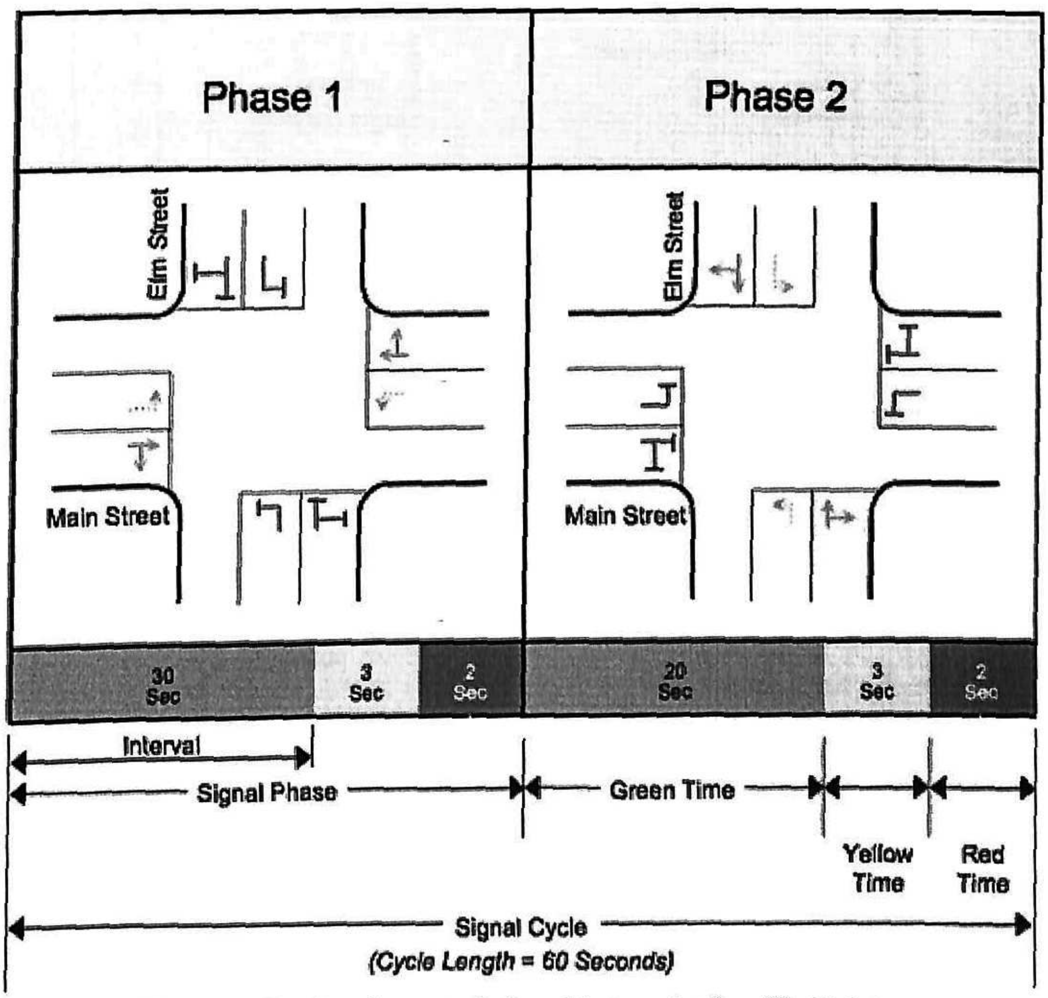

Figure 5. Cycle, phase and signal interval of traffic lights

In the United States, two more definitions are added that are key to automating the regulatory process:

- Section of regulation (Split). The percentage of the control cycle allocated to each of the control phases.

- That is, by varying the percentage of time per phase, you can control the duration of the green signal on the most loaded direction. At a separate intersection, this gives a reduction in delays.

- Offset. The difference (in seconds or percent of the control cycle) between the clock at a particular intersection and the master clock (on a network of intersections).

Figure 6 shows a diagram that explains these functions very well.

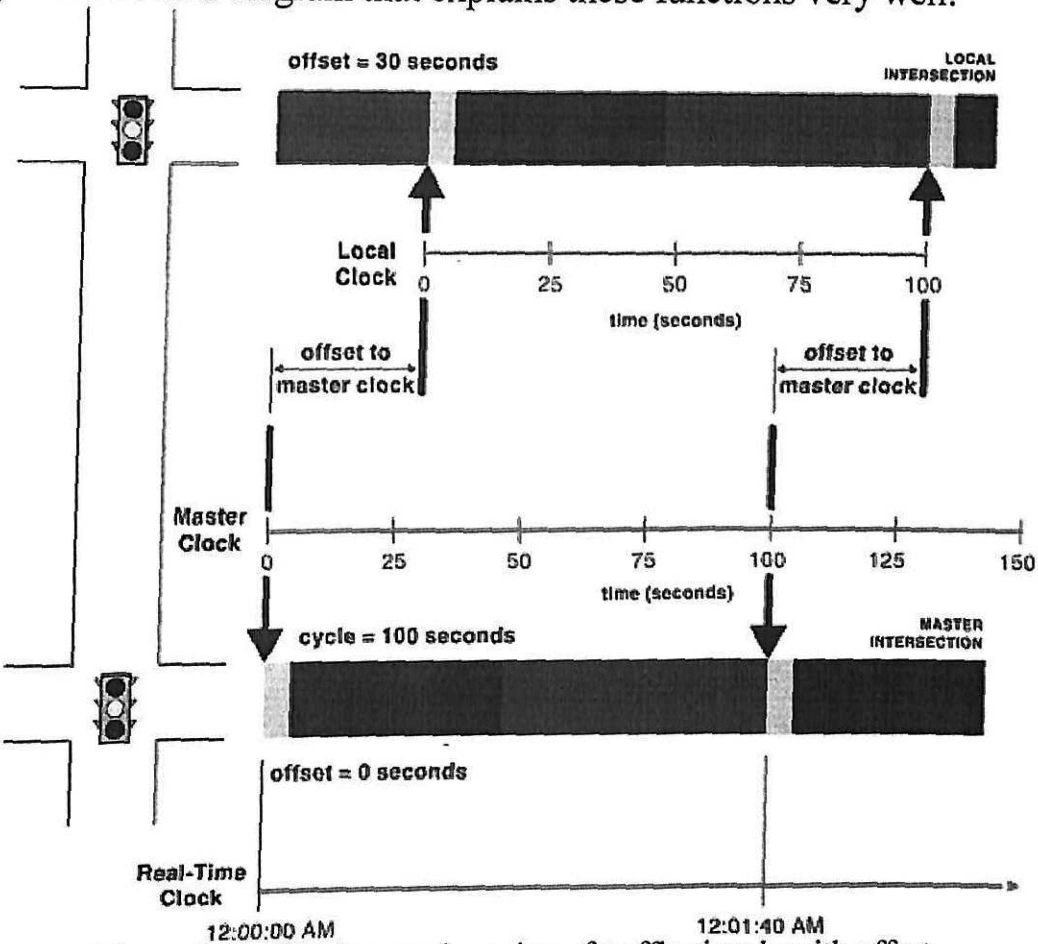

Figure 6. Cycle, phase and spacing of traffic signals with offset

It can be seen that the phases at the adjacent intersection are shifted relative to the previous one. Time displacement is just enough for a group of cars to drive up to him and slip into the green. The calculation is usually carried out for some average speed accepted in the given region. Therefore, "racers" and "brakes" as a rule break down on such highways.

Here you can read about all of this in detail. From there the last picture.

1.2.3 Intelligent traffic control system

Intelligent traffic management system is a specialized software ITS and an interconnected complex of high-tech equipment for the organization and management of traffic.

Main purpose of the system:

- Optimization of traffic on regulated traffic lights in order to reduce transport delays;
- Reduction of the time spent for the trip;
- Increase the operational speed of public transport.

The firmware includes the following subsystems: centralized traffic management, video surveillance and traffic control systems, and control of variable information signs. In the future, it is planned to introduce additional subsystems for the management of car parks, public transport, including the provision of priority passage of LRT and BRT, informing passengers.

The work of the whole system is based on the collection and analysis of current data coming from detectors, data collected earlier in operation, and data from the navigation equipment of public transport, if the priority program is involved. All information is sent to the Traffic Management Center (CTC), from where coordinated control of all traffic in the city is carried out. Specialized software coordinates the operation of traffic controllers for traffic lights and allows you to adjust traffic, both in the adaptive mode and in the mode of choosing coordination plans.

Intelligent traffic management system uses data continuously coming from transport detectors and makes necessary calculations in real time. Thus, the system solves the global traffic optimization problem, responding to the current transport situation. At the local level of a separate traffic light object, the system constantly adjusts the control strategy developed by the CTC, proceeding from constantly updated current information on this and neighboring objects, that is, adapting to the current transport situation.

1.2.4 Positive experience of the functioning of traffic lights with automatic regulation in cities of developed countries

The first attempts to centralize the traffic lights were made in the US and Canada in the far 60s of the last century. At the moment, the Smart Traffic Light system is widely implemented in all developed Western countries (USA, Great Britain, Denmark, etc.). In Copenhagen, even planned to install about 400 smart traffic lights, which at intersections would give an advantage to cyclists and public transport. This is planned to allocate about 9 million US dollars of budgetary funds. According to the city authorities, this decision will allow cyclists and city transport to travel around Copenhagen by 10 and 5-20% faster, respectively.

Many of the mega-cities of Southeast Asia collided with traffic congestion problems in their time: Beijing, Seoul, Hong Kong, Singapore. Intelligent transport systems helped solve the problem of traffic jams.

Intelligent transport systems help to solve the problems of both drivers and passengers. The first include automotive information and communication systems. In Tokyo, roadside sensors and lighthouses were installed twenty years ago, and drivers in online mode could receive traffic data and bypass routes. Multifunctional transport portals, which are broadcast around the clock from street cameras, are in Hong Kong and Korean Incheon.

To services for drivers also include dynamic road signs and scoreboards that inform the driver about bad weather conditions, congestion on the road. Usually, these signs work on LEDs and are connected to spare generators, so they can function even in the event of an energy collapse.

In many European cities there is a parking assistance system, which not only provides information on available seats, but also prompts the addresses of the nearest parking lots. Finally, to pay for a toll road, drivers from Australia and Southeast Asia do not need to use the services of a parking lot and even more so - stand in lines. On many routes there are cameras that photograph the number of the car. The fare is debited from the credit card of its owner, you can check the balance and set up a suitable payment mode on a special website.

In addition, intelligent transport systems help identify incorrectly parked cars, carry out rapid evacuation of victims in the event of an accident and promptly reprogram traffic lights to unload the overcrowded trails. So, in Hong Kong, from several closely located intersections of roads often make a "green street", so that the flow, freely passing one intersection, did not linger on the next.

Intelligent transport systems for passengers are primarily terminals that collect and quickly transmit information on public transport traffic to interactive screens. Seoul created a free bus application for the iPhone. In English Leicester you can find out the reasons for the delay of the bus by sending an SMS-request. In some countries, there are free hotlines where the passenger can find out the exact waiting time for the bus or tram.

Special services are designed for pedestrians. In Singapore, an elderly person or an invalid is unlikely to risk his life, trying to run across a busy highway. It is enough to bring a smart card (an analogue of our social card) to the traffic light reader - and the green light will burn exactly as long as an unobtainable person needs to get to the sidewalk on the opposite side of the road.

And, of course, one of the main inventions of intelligent transport systems is an intelligent traffic light. The world's accumulated experience allows us to positively evaluate the work of such systems. Smart traffic lights began to appear since 2001 in the major cities of Great Britain, Japan, Italy, the USA and other countries.

The traffic light control system regulates transport and pedestrian traffic lights. At intersections and junctions, the sensor wires laid under the asphalt determine the approximate number of machines that have accumulated in this direction, and the green light burns longer for that highway where the load is now greater. In Hong Kong, out of several closely located intersections, roads often make one "green street", so that the flow, passing through one intersection, does not linger on the neighboring one. In 2005, Los Angeles computerized traffic lights became the first to miss the bends, as a result, the speed of buses around the city increased by a quarter.

In modern automated traffic management systems, common in most European countries, information from video cameras that are part of video monitoring subsystems is widely used. The information obtained from them allows to organize the optimal management of traffic flows, coordinate the work of key transport hubs of the city, etc.

The principle of the video control system is widely known. A video camera is installed above a certain section of the road, transport junction, highway, dangerous section of the road at a certain height. The signal from it goes to the video processing module. In this module, mobile vehicles are allocated and various integral estimates are determined. Further, in the control center, both numerical data can be obtained, for which a low-bandwidth channel is sufficient, and a video image directly from the monitored area is sufficient.

Video-oriented transport systems provide data of three types:

1. Traffic information for statistical processing

- total number of vehicles detected;
- speed;
- acceleration of traffic flow;
- flux density;
- busy lanes;
- classification of cars.

2. Information on incidents on the road:

- high speed, flux density or busy bands;
- presence of congestion or traffic on the opposite lane;
- stopped or slowly moving cars;
- presence on the road of suspicious objects.

3. Information on the presence / absence of cars:

- the presence of approaching cars;
- the presence of cars stopped at the intersection;
- the number of vehicles passing through the detection zones;
- measuring the length of the queue.

The latest type of information, as evidenced by the experience of foreign countries, is widely used in traffic light control systems. The video monitoring system is integrated into the traffic light control module, which allows to coordinate the operation of all traffic lights of the intersection in any tight transport unit.

But the impetus to the technical modernization of control systems and traffic control in European countries was the experience of France.

In 2003, a new law "On changes in traffic rules" was adopted, which envisaged a significant tightening of sanctions for violations on the roads.

And only then the technical modernization of roads was carried out: the traffic lights in the cities began to be produced from a single center; On the main routes, new cameras connected with the radars were installed, which automatically detected speeding, fixed on the film the number of the car, the face of its owner. These data were transmitted to a central computer, which, without the participation of a person, wrote a fine to the owner of the car.

Thanks to these innovations, the number of road accidents on French roads declined by a third in two years.

Nevertheless, in individual states there are specific features of the technical organization of the movement.

So, in Barcelona (Spain), urban traffic is also regulated by "smart" traffic lights. They are programmed in such a way as to maximally provide public transport with a "green street".

Due to the analysis of traffic and GPS-beacons, which are equipped with municipal facilities, "smart" traffic lights are also adjusted for the movement of emergency services. If an accident has occurred in the city, traffic lights will ensure the fastest arrival of rapid response services to the place of the event.

In Switzerland, Zurich created an intelligent system that is capable of self-learning and saves time and gasoline of car owners, and also significantly reduces the burden on the environment.

The smart traffic light works according to the following principle: in case the car stops at the intersection, where the red light is in its direction and the transverse street is empty, the traffic light in this direction switches to green light and the car passes calmly, without losing time on a simple one on the red Color.

However, the fact is that such a traffic light at a separate intersection will not only not be useful, but also harmful: there are fast congestions at neighboring intersections. For normal operation, it is necessary to link everything into a single system. Using methods of computer modeling, experts from Zurich managed to achieve the desired result: several traffic lights most of the day work in the "evergreen mode."

However, such an approach on a single territory has little chance to spread everywhere. The fact is that the overwhelming number of European streets are equipped with traffic lights of the sample of the 60-70s of the last century. And to combine such traffic lights with modern computers is simply senseless. Therefore, it takes a lot of time and effort to implement the above system of smart traffic lights everywhere.

If we consider the experience of Japan in introducing an intelligent transport system, it is one of the most revealing. The Japanese capital, Tokyo, which is one of the largest metropolitan areas in the world, has about 13 million inhabitants, struggles daily with congestion on the roads, and multi-level interchanges, a large number of sensors and smart traffic lights help it. The entire system is working successfully, as evidenced by a significant reduction in congestion on the road.

All data from video cameras and sensors are received by the Tokyo Police Control Center. At the same time, all functions can be controlled from any computer, in this connection, usually no more than five operators sit on the site. On the computer screen, the entire metropolitan road network is displayed from the usual highways to highways. The color shows the situation with traffic, where the green - the road is free, red - on the road jam. The color of the roads changes in real time.

On a high-speed highway, traffic is less than 60 kilometers per hour, on an ordinary road - 40. 20 kilometers per hour is already considered a "catastrophic traffic jam".

The Transport Police Center of the Tokyo Police was opened in 1995 and since then its work has been constantly improving. One of the advanced technologies is the ultrasonic sensor, which is installed on the Tokyo roads. They determine the density of the transport stream and transmit the data to the Transport Control Center. In addition, throughout the metropolis there are 17 thousand infrared detectors, signals from which come directly to the navigators of passing cars, so that motorists can choose a more convenient route.

In Tokyo, more than 15 thousand traffic lights, and, depending on traffic, you can remotely control the time of supply of green and red signals.

According to statistics, the number of road accidents on the roads of Tokyo decreases every year. All this thanks to innovations in the field of regulation of traffic flows. So, for example, smart traffic lights react to the approach of pedestrians on yellow tracks, equipped especially for the visually impaired, - these are highlighted on almost every sidewalk.

Among the main market players offering specialized solutions for smart traffic lights, one can distinguish IBM, SCOOT, SCATS, RHODES, UTOPIA and others. In 2010, IBM even planned to make a patent that would allow remote disconnecting the engines of cars driving through the red light.

According to the plan, the system was to receive information from cars that approach the intersection, analyze their relative position, take into account the time left before switching on green light - and, if necessary, send a signal to the vehicle's computer to switch off the engine. When the green light comes on, the first signal to switch on will receive the first car in the queue for traffic, and all the following - after a certain calculated time period.

In the patent it was assumed that such a system could be interfaced with traffic lights working at the most strained intersections, railway crossings. The goals were the optimization of the traffic and fuel economy. The engine can be switched on and off either completely automatically or with the help of the driver, by supplying the required signal at the right moment.

Indeed, when driving along a street in a dense stream, through intersections, it is at the intersections that the main time is spent - and quite a bit of fuel: although the car does not go, its engine continues to work. In some cases, it would be possible to turn off the engine, but in this case it is extremely difficult to calculate the optimum moment, because to restart it requires additional fuel consumption, sometimes more than can be saved. This new computing system was planned by IBM.

All the necessary information is taken from the control system of traffic lights, GPS-modules of cars, video cameras and other sensors located at intersections. It was understood that such a project will be realized as a paid (but inexpensive) service for drivers, subscribing to which you can win in saving fuel.

To date, this idea is not implemented by IBM.

Consider in more detail the experience of the United States in the introduction and use of smart traffic lights. Initially, the traffic lights were autonomous objects that operated according to a schedule built into them in advance. With the growth of urban infrastructure and the development of information technology, in developed countries they have become interconnected via the Internet system, regulated with the help of special equipment that monitors urban traffic.

At the same time, it is worth noting that the Wi-Fi-related traffic signals in the US have their drawbacks, such as hacker attacks. So, a potential hacker can interfere with the operation of almost any of these traffic lights.

The researchers found that the network is at great risk due to virtually nonexistent or primitive security protocols, while highlighting the three main vulnerabilities - unencrypted data transmitted between the traffic light infrastructure, the simplest and standard logins and passwords to access them, as well as easily detectable debug ports .

The simplest and most effective method for eliminating the current situation is changing the logins and passwords for access to a particular object for more complex ones. And also coding information exchanged via Wi-Fi traffic lights.

In Russia, the first smart traffic lights appeared in Moscow about 10 years ago. The tests were carried out on an experimental site of 7.5 km. The sensors along the roads monitored the density of the traffic flow and transmitted this information to a single control center, which, based on the received readings, optimized traffic lights at intersections. As of the beginning of 2015, a significant part of metropolitan traffic lights were already connected to the automated traffic management system. In early 2016, information appeared that the main traffic lights in the capital began to control not only traffic density. Weather conditions and road accidents were also taken into account.

Thus, data on heavy snowfalls, accidents or harvesting equipment comes from a dynamic model, then the automation determines the mode of operation of traffic lights, allowing the maximum number of cars to pass.

To date, projects to introduce smart traffic lights are developing in other large Russian cities - St. Petersburg, Sochi, Kazan, Chelyabinsk, Novosibirsk, Omsk, Yekaterinburg and others. In addition, an innovative adaptive traffic light was developed in the Russian company Rostech: a special controller was created to manage the traffic lights. Controllers provide traffic light communication with the dispatch center via the Internet and are equipped with a traffic information collection module, which, depending on the particular road, includes up to eight detectors of various data.

Thus, the experience of developed countries in the implementation and operation of traffic lights with automatic control clearly shows how such innovations not only improve the situation on the roads, reducing the number of congestions and accidents, but also contribute significantly to reducing pollution in the atmosphere and generally improve the state of the environment.

2. ANALYSIS OF THE ROAD TRANSPORT SYSTEM IN LARGE CITIES OF THE REPUBLIC OF KAZAKHSTAN

2.1 Analysis of street-road networks and traffic flows in large cities of the Republic of Kazakhstan

In the Republic of Kazakhstan, as in other countries, transport is one of the largest basic branches of the economy, the most important part of the industrial and social infrastructure. Transport communications unite all regions of the country, which is a necessary condition for its territorial integrity, the unity of its economic space. They connect the country with the world community and they are the material basis of ensuring foreign economic ties of Kazakhstan and its integration into the global economic system.

The transport plays an important role in the socio-economic development of the country. The transport system provides conditions for economic growth, improving the competitiveness of the national economy and the quality of life of the population. Geographical features of Kazakhstan determine the priority role of the transport in developing the competitive advantages of the country from the position of realizing its transit potential. Access to safe and quality transport services determines the efficiency of work and development of production, business and social sphere. In this regard, the role of transport in the socio-economic development of the country is determined by a number of volume, cost and quality characteristics of the level of transport services.

Analysis of the system of inter-factor interactions requires additional comparison of their dynamics. For example, the anticipated growth of the vehicle fleet (by 60%, to 3.64 million units) in combination with the inadequate rates of its renewal (the level of depreciation decreased by 7.4%) led to an increase in the load on the road infrastructure, an increase in the cost price, accidents and a general decrease of the industry efficiency. At the same time, transport costs amount to 8-10% of the final cost of Kazakhstani goods, in contrast to 3.5-4.5% for developed countries.

In our country, Almaty and Astana have the highest rate of motorization. In these cities the security of the population of cars is at the level of some countries in Western Europe. So, according to the Ministry of Internal Affairs of the Republic of Kazakhstan at the beginning of 2016, the level of motorization in Almaty is 342 cars per 1,000 inhabitants, in Astana is 319.

In these cities congestion occurs due to low road capacity; disorderly parking of vehicles on the carriageway; a lot of traffic lights and time wasting while waiting for their switching; lack of pedestrian lanes and disorderly pedestrian crossings; unpopularity of public transport; culture of drivers, lack of mutual respect; disorderly movement of special equipment and heavy cars; unregulated (on time) carrying out of repair-civil work and improvement of a road strip. Narrowing of roads (when 5 lanes pass into 2 or 3 lanes, thereby causing drivers to rebuild at very low speed). Congresses at two-level interchanges without acceleration and rebuilding bands form unregulated intersections, which inhibit the main and adjacent flows. Unsatisfactory condition of the road (potholes, pits). At each traffic light and in places of congestion, the amount of automobile emissions is very high, since under idling and speed dialing conditions, huge volumes of exhaust gases are released into the atmosphere.

In Almaty, on the roads, as a rule, half of the first row is occupied by cars parked in the wrong place, and the left-hand row, though freer, stops moving as it approaches the intersection. Because not every intersection has a traffic light with an additional arrow, and in the end, only 3-4 cars rotate on average in one period. In addition, there are very few intersections in large cities of Kazakhstan, where there is a separate section for turning left. As a result, cars are hammered in a whole series and significantly reduce the throughput of the intersection. To solve these problems, it is enough to prohibit the left turn at the intersection and to start the entire flow of vehicles to the right and forward, so that after traveling to the break in the dividing strip, wherever they turn left, by that can speed up the flow of cars and do not take up a whole strip.

In general, for the cities of the country road transport is the most mobile type of transport, which accounts for a larger percentage of the total volume of passenger and cargo transportation by all modes of transport. At the same time, the share of road transport in general passenger turnover and freight turnover of Kazakhstan prevails. According to the data for the end of 2013 - the beginning of 2014, in the Republic of Kazakhstan there were registered more than 4.2 million vehicles, including 3.6 million cars, 429 thousand trucks and special vehicles and about 97 thousand buses, that operate in 34 bus terminals and 138 bus stations in accordance with figure 7.

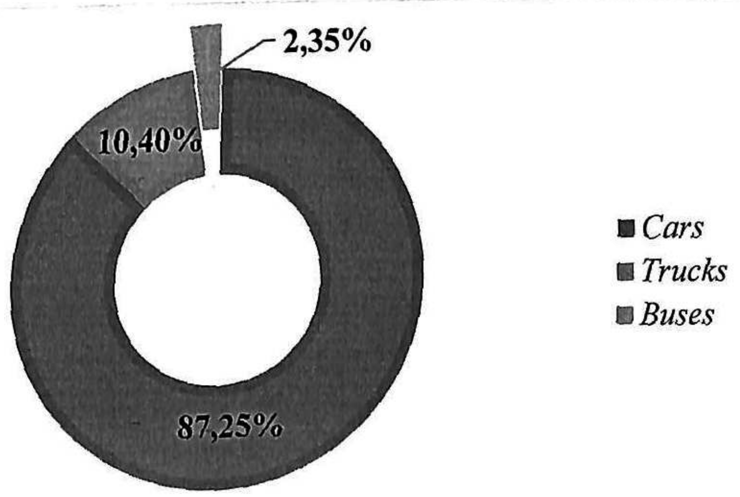

Figure 7 The ratio of different types of vehicles in the market of passenger transportation in Kazakhstan according to 2013, %

The Government of Kazakhstan pays much attention to the development of passenger transportation by road, which is reflected in the growth of traffic. The work was carried out to bring the services of depots, bus stations and passenger service points, as well as transportation of passengers by buses and taxis in accordance with national standards. The program of the transport complex development provides for bringing all depots and bus stations in compliance with national standards by 2020.

In order to develop electronic dispatch and ticket sales at the legislative level are provided regulations for equipping buses with navigation system devices. Electronic dispatching of city routes has been introduced in Astana and Almaty, as well as in Aktobe, Atyrau, Pavlodar, Zhambyl, Karaganda, North Kazakhstan and West Kazakhstan regions, as well as on intercity and international passenger routes.

The total number of motor vehicles in Kazakhstan has doubled in the last 7 years. In the period from 2006 to 2013, the number of vehicles increased from 2 131.9 thousand to 4 200 thousand units in accordance with figure 8. Kazakhstan's official automobile market in January-October 2014 showed an increase of 3%, which is slightly less than 134 thousand cars.

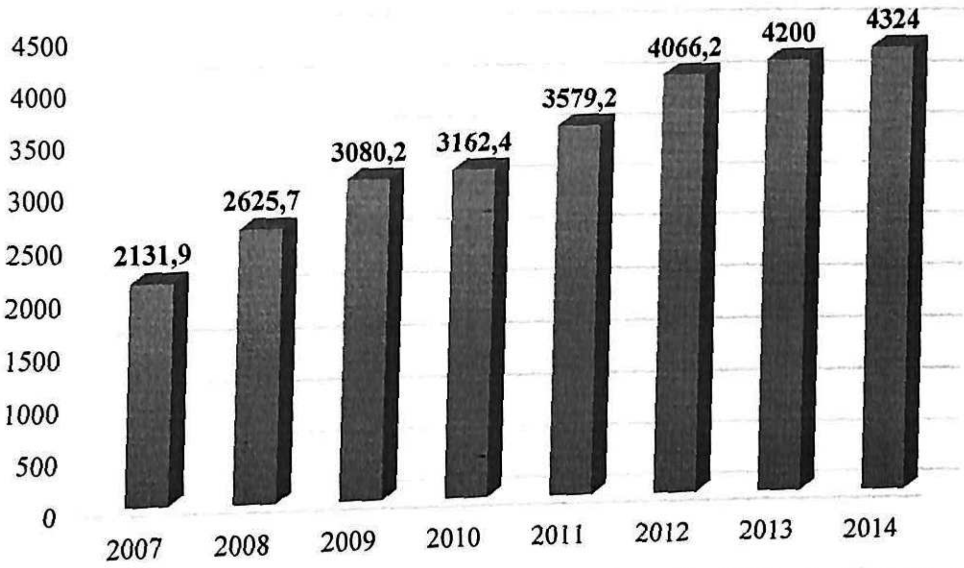

Figure 8 Dynamics of increase in the total number of vehicles in Kazakhstan, thousand units (as of the end of the period)

In general, the share of passenger transport (buses and cars) in the regions of the republic is on the average 30-40%. A comparatively low number of provision with passenger transport is observed in the following regions: North Kazakhstan (28,8%), Kostanay (33,3%), Kyzylorda (33,5%), Zhambyl (33,7%). The highest level of passenger transport was registered in Almaty (49%), Astana (49.6%), South Kazakhstan (39,2%), Atyrau (39,1%), Almaty region (37,2%), Pavlodar region (36,6%), East Kazakhstan region (36%). Most of all cars as of February 2014 were recorded in Almaty. Here the number of cars is 502.4 thousand units. Concentration of vehicles per 100 population is estimated at 33,0. As the statistics show, the largest share falls on individuals who own 491,8 thousand cars in the city, or 97,9% of the total (Table 2).

Table 2 Availability of cars in the Republic of Kazakhstan in 2014 (units)

Region	Total cars, units	Based on per 100 population
Almaty	502 439	33,0
Almaty region	459 028	23,0
South-Kazakhstan region	381 231	13,8
East-Kazakhstan region	327 948	22,6
Karaganda region	320 933	23,0
Jambyl region	235 510	21,2
Astana	234 341	27,6
Kostanay region	167 289	18,9
North-Kazakhstan	162 877	26,9
Pavlodar region	152 910	19,8
Akmola region	143 652	188
Atyrau region	131 746	22,3
Aktobe region	131 439	15,5
Kyzylorda region	115 055	14,9
West-Kazakhstan	98 141	15,5
Mangistau region	93 166	15,7

At present, Almaty, along with Astana, the capital of the Republic of Kazakhstan, has the status of a city of national importance. According to the Almaty Department of Statistics, as of early 2014, more than 1.5 million people lived in the city. After the recent accession to Almaty of 23 thousand hectares of land, the city's territory has increased to 80 thousand hectares. Thus, in accordance with figure 9, the population of Almaty today is 1 million 700 thousand people.

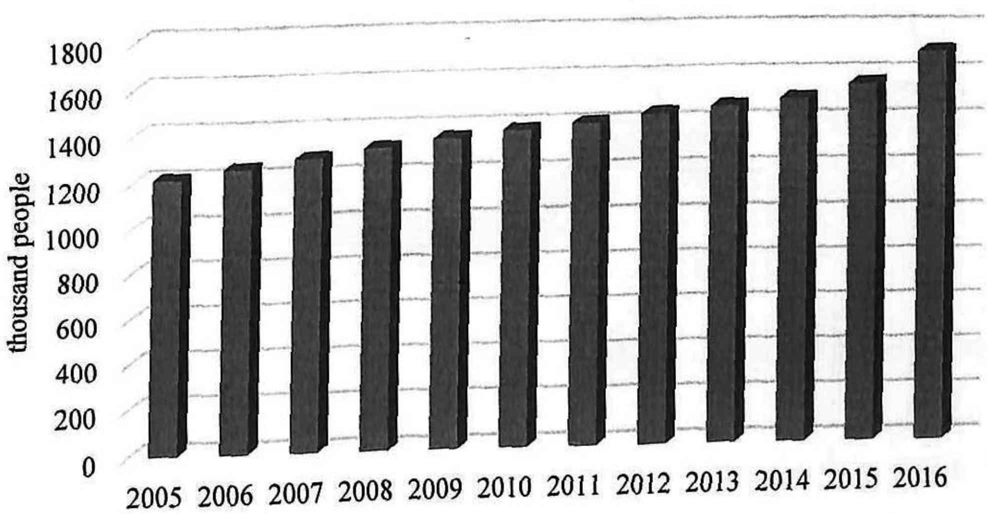

Figure 9 Dynamics of changes in the number of residents of Almaty, thousand people. (As of January 1, 2005-2016)

The annual migration increase of the population of Almaty in the last 2-3 years is about 10 thousand people. As experts predict, by 2020 the number of people living in Almaty will increase by 100-120 thousand people, and by 2050 the population will reach 2.5 million people.

In addition, Almaty is the leader among Kazakhstani cities in terms of the number of tourists. So, in 2014 the number of foreign visitors reached 800 thousand people. According to the results of the study of the famous British edition for tourists, Almaty entered the top 10 cities of the world, which are worth a visit.

On the further popularization of the city and the country, large-scale projects will well impact: the ski resort «Kok-Zhailau», EXPO-2017 and, possibly, the Winter Olympics of 2022. According to experts, the number of tourists in Almaty will increase eightfold by 2020.

The current public transport network in Almaty consists of 1 metro line, 110 bus routes, which serve 1,869 public transport units and 12 trolleybus routes.

Almaty subway consists of one line with 7 stations. Metro in Almaty passes, mainly, through the central districts of the city.

In addition, the city has 15 taxi depots, which have contractual relations with the Office of Passenger Transport.

As can be seen from the data in accordance with figure 10, there is a positive dynamics of passenger and freight turnover growth for all types of transport in Almaty, while the maximum growth in passenger traffic is observed in the trolleybus segment, but its share in the city transport system is low.

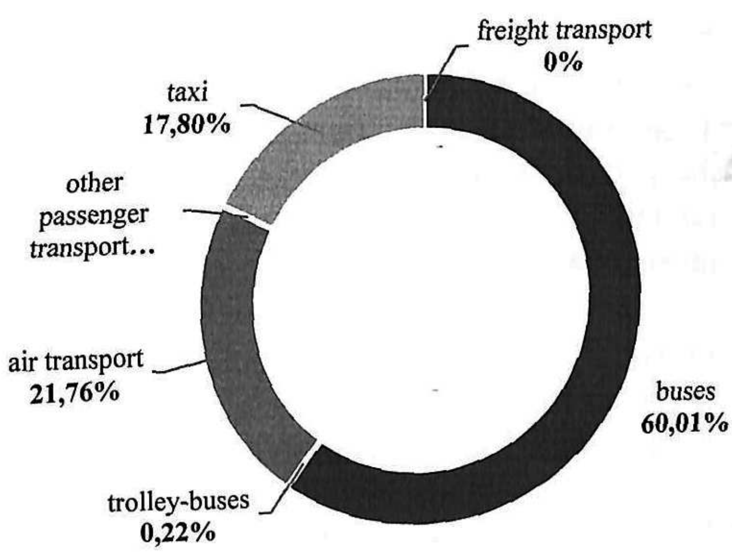

Figure 10 Structure of passenger turnover by transport organizations in Almaty in 2015, %

Thus, currently less than 30% of all trips within Almaty are made by public transport.

According to the statistics department of Almaty, the number of legal entities registered in the city with the main activity "Taxi activity" increased almost twice from 2009 to 2013, from 20 to 38, of which active from 5 to 12 in accordance with figure 10.

The territorial segmentation of transport enterprises in different parts of the city is shown in figure 11, according to the Department of Statistics of Almaty.

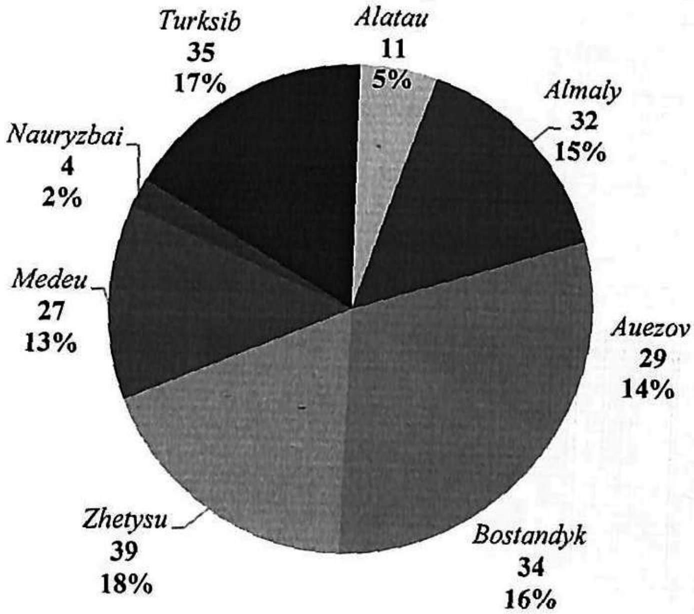

Figure 11 Structure of transport enterprises in Almaty by districts, %

In 2010-2016, the Almaty Akimat achieved significant results in the development of transport infrastructure. In particular, the following activities have been implemented:

1. The dispatching system for monitoring the operation of public transport and the final pivotal platforms for the sagging of the rolling stock and the rest of drivers were restored, construction of new stops are being built.

2. In addition, to strengthen competition among carriers, the first communal bus fleet has been built and the rolling stock of public transport has been significantly updated: modern trolleybuses, gas low-floor buses that meet international standards.

3. In the first half of 2014, gas buses were acquired for a loan from the European Bank for Reconstruction and Development.

4. A transport holding company has been set up, which today exercises strict control over the quality of public transport services.

5. Taking into account the wishes of Almaty citizens and guests of the city, a bus route was organized in express mode from the airport to the center of Almaty.

6. On a regular basis, the express routes Center-Medeu are launched at the weekend.

The new Master Plan laid the punching of the Great Almaty Ring Road (GARR). For the coming years, it is planned to build capital modern commercial and residential complexes.

At the same time, a number of problems remain unsolved. The average speed of buses and trolleybuses in Almaty is 15.5 km/h in the morning rush hour. Speed in the city center is even less. Below in figure 12 there is a screenshot from the service «Yandex. Corks», illustrating the difficult situation with the density and speed of traffic in the center of a large city at 8:30 am on a weekday (Almaty is used as an example).

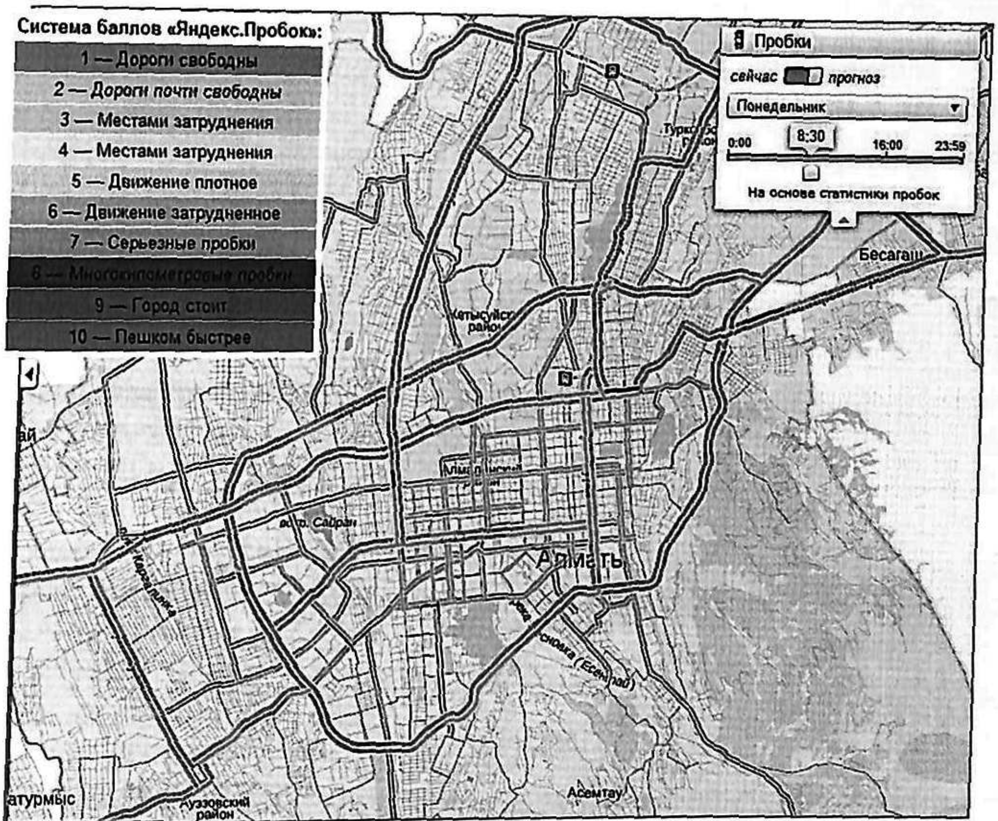

Figure 12 Transport tension in the center of Almaty

Among other problems of public transport functioning in Almaty are the following:

- lack of integration of different types of public transport;
- free and uncontrolled parking in the city center/no receipts to the city budget;
- lack of priority for public transport on roads and traffic lights;
- insufficiently developed infrastructure for tourists and visitors of the city.

In 2013, with the assistance of UNDP-GEF, «The sustainable transport strategy of Almaty for 2013-2023» was developed and adopted, which will improve the quality of life in Almaty, an attractive city for life and work. This document assumes the following tasks:

- the opening of two new metro stations;
- construction of new bus stations with intercepting parking for commuter transport;
- inventory and drawing up a plan for the reconstruction of the stopping kits;
- the formation of pilot areas in the city center with paid parking;
- improvement of pedestrian crossings on the main streets and in the city center;
- improving the system of information / interaction with passengers (at stops and through mobile Internet applications).

Key parameters of «The sustainable transport strategy in Almaty for 2013-2023» and its impact on the development trends of public transport in Almaty in the medium and long term are given in the Table 3.

Table 3 Trends and prospects of transport sector development in Almaty

Parameter	2012 (actual condition)	2023 (inertial scenario)	2023 (in the implementation of The sustainable
Average speed of vehicles [km/h], (morning peak)	19.1	15.0	18.3
Average speed of public transport [km/h] (morning peak)	15.5	1.8	19.2
The total time spent on the road, daily (by motorists and passengers of the PT)	300,000 hours	700,000 hours	400,000 hours
Percentage of the population living 500 meters from the station of mass high-speed modes of transport	8%	18%	51%
Percentage of people traveling by bicycle from total	Less than 0.5%	1.5%	6%
Percentage of travel by sustainable means of transportation (on foot, by bicycle, public	42%	35%	55%
The number of movements on vehicles and the total length of such trips (daily)	1.13 M trips /10.34 M	1.85 M trips /20.04 M KM	1.37 M trips /14.10 M KM

Thus, making an intermediate conclusion, we can say that there is the need arises for the implementation of the public transportation project in Almaty, which generally meets the current market requirements, since it will improve the system of information and interaction with passengers at stops, which will contribute to the implementation of The sustainable strategy transport in Almaty. These events also correspond to the overall concept of building the «Smart City» in Kazakhstan, created for EXPO-2017 in Almaty and Astana.

The key core of the «Smart City» is ICT, which will ensure the collection, transmission, processing of information from hundreds of thousands of sensors. This, in turn, will ensure the optimal mode of operation of all urban systems: in particular, «Smart transport» systems (passenger transport), which will increase the speed and reliability of transport communications in the city.

2.2 Analysis of the environmental situation associated with the road transport system of the cities of Kazakhstan

Exhaust gases of vehicles contain harmful substances, such as hydrocarbons, nitrogen oxides and carbon oxides, chlorine, sulfur dioxide, phosphorus, aldehydes, etc. These components have a negative impact on the environment, worsening environmental performance, especially in cities. According to statistics abroad, more than 40% of emissions of harmful substances into the atmosphere are in road transport, and in Kazakhstan, this figure is 31%.

It is alarming that despite the ongoing work, emissions of pollutants into the atmosphere from vehicles are increasing by 3.1% per year on average.

More than 70% of nervous disorders in urban residents occurs as a result of noise effects on the human body. Such negative effects lead to the development of fatigue, insomnia, heart disease. The specific gravity of noise impact in the city is about 80%. The noise level in cities located in the urban highways area is in the range from 70 to 75 dBA, while the norm is 40-50 dBA in the daytime, 30-40 dBA - at night.

It is established that there is a dependence of the intensity of motion on the noise level. When the intensity is increased to 1000 auto/h, the noise level rises by 10 dBA. This indicator also has a dependence on the speed of traffic flow.

In addition to noise, vehicles have a negative impact on the environment. Such an effect is the emission of harmful substances into the atmosphere. As additive, a compound called tetraethyl lead is added to the fuel. When burning a liter of gasoline into the air comes 0.2-0.4 g. of lead. As a result, when burning fuel, the amount of harmful substances per year is up to 26 thousand tons, which is almost 100 times higher than the intake of lead during volcanic eruptions. The amount of harmful emissions to the environment during the combustion of one ton of leaded gasoline is 0.65 kg. oxides of lead.

An important problem of the deterioration of the environment is the smoke of cars. The causes of car smoke are different: this is engine malfunctions, not the power supply system or ignition. If all car engines are properly adjusted, the emission of harmful substances into the atmosphere will be reduced by about 2 times. Violation of technological discipline, unwillingness to spend an extra hour digging into the engines lead to the fact that the car for weeks, and even months, razed the streets with poisonous gas. Poorly inflated tires not only wear out faster, but also increase resistance to movement, which means that more fuel is burned.

Inadequate behavior of the driver behind the wheel (improper choice of driving speeds, sudden acceleration and braking, increase in the set speed), as well as self-adjustment (increasing the idle speed) and violation of the car operating instructions often lead to increased environmental pollution, reducing the effectiveness of design efforts. Therefore, explanatory work among drivers of cars in this direction is very important.

The main contribution to the pollution of the atmosphere is made by cars running on gasoline (75%), then cars with diesel engines (about 9%), tractors and other agricultural machinery (about 4%)

It is established that annually one passenger car, absorbing 4 tons of molecular oxygen, releases into the atmosphere 0.8 tons of CO, up to 40 kilograms of various nitrogen oxides, up to 200 kilograms of hydrocarbons, in addition, soot, tetraethyl lead and other substances (aldehydes, organic acids, polycyclic hydrocarbons and their derivatives).

Diesel-fueled engines emit less carbon monoxide into the environment, but more carbon dioxide and sulfur dioxide. The least amount of harmful impurities is contained in the exhaust gases of engines operating on liquefied gas (CO is five times less than that of carburetor engines, nitrogen oxides are doubled, and sulfur oxides are absent).

The composition of the exhaust gases depends largely on the engine-operating mode. So, the content of CO is: idling 0.5-6.5, with a constant speed of movement - 0.3-3.5, with acceleration (from 0 to 40 km/h) - 2.5-5.0, at braking (from 40 km/h to 0) – 1.8-4.5% in volume. For nitrogen oxides: 0.005 - 0.01; 0.1-0.2; 0.12-0.19; 0.003-0.005 (respectively with CO). Exhaust gases contain carcinogens (substances that contribute to the development of cancer), such as benzpyrene.

Analyzing the above information, it should be noted that the composition of exhaust gases depends on both the type of engine and the mode of operation of transport, which is important to consider when implementing environmental measures.

As a result of the research, it was revealed that when the engine is idling, carbon oxide emissions amount to 6%, and when driving, this figure is significantly less - 2%. Provided that the vehicle engine is running at idle for most of the time, it is necessary to reduce the idle time with the running engine of the vehicle when driving in the swing state of the traffic flow.

A large number of harmful substances enters the atmosphere at:

1. delays of the vehicle in front of traffic lights;
2. parking with engine running while waiting for an enabling signal;
3. starting from the site and dispersing.

In order to reduce emissions of harmful substances, it is necessary that the traffic flow is in a free state during the movement of the vehicle.

The length of the main streets is about 20-30% of the total length of street-road networks. Since the main streets are the busiest sections of the street-road networks, it is up to 75% of all vehicles moving within the city that are concentrated on them. Consequently, the territories along the main streets require special attention to improve the ecological situation.

The device in the cities of the highways with high speed provides an increase in the capacity of street-road networks, reducing the number of accidents, isolating residential areas and making centers of attraction from the presence of traffic flows with high intensity, and, consequently, improve the environmental situation. However, the highway for high-speed traffic is an expensive construction. Its construction justifies itself only in areas where traffic flows are constantly present, having long-distance trips on the territory of the city. As a result, highways are intended only for the largest agglomerations.

It is worth noting that, despite the obvious advantages, smart traffic lights cannot completely solve the traffic congestion problem. The smart traffic light system is only able to maximize the performance of the intersection. At the same time, the city authorities will still have to expand roads and build complex traffic interchanges. According to analysts, one city strip on average can serve no more than 1800 cars per hour. And this is provided that the vehicles do not stop at intersections and do not face such obstacles as narrowing the road, unsatisfactory quality of the roadway, etc. As the number of cars in our country is steadily growing, it is obvious that even with the maximum productivity of intersections, traffic jams in large megacities will grow, if only deal with the implementation of «Smart traffic» and not solve other road problems.

2.3 The need to introduce new developments into the existing system of automatic regulation in the Republic of Kazakhstan

2.3.1 Existing systems of automatic regulation of traffic flows in the Republic of Kazakhstan

According to experts, the market of transport navigation of the Republic of Kazakhstan is still characterized by low concentration and is at an initial level of its development.

In general, the Kazakhstan market of navigation systems and technologies follows in the wake of the Russian market, repeating its trends with some lag. It should be noted that in 2012-2014. The Russian navigational market on motor transport has grown twice.

According to GLONASS analysts, the driver of the growth of the navigation market is currently the development of the services market: insurance telematics, technical support on the roads, information services.

Today, four navigation programs successfully compete in the market of Kazakhstan: Garmin Mobil, City Guide, Navitel Navigator, Prestigio. Two of these brands are Russian:

1. City Guide - car GPS/GLONASS navigation system, produced by the Russian company MIT LLC. Versions are available for: Windows Mobile, Windows CE, Windows Phone, Windows XP/Vista, iPhone, Java, Brew, Symbian S60 ed.3 and S60 ed.5, Android OS. In addition, there is a version for built-in car navigators AutoVAZ Lada Kalina, Priora, Ellada. The program is distributed both on a fee basis, and there are free versions with reduced functionality.

Features of the system:

1) Search by addresses and objects on the map.

2) Service information about traffic jams. The technology of own development, protected by the patent is used.

3) Online correction of maps (automatic mapping of changes in the order of motion caused by the installation of new signs, such as "brick", rotation prohibition, one-way traffic, etc., road works, etc.) - without the need to update themselves Maps and / or program reboot.

4) Customizable POI display filter (points of interest (gas stations, shops, cafes, places of rest, etc.).

5) A customizable DPOI display filter and the ability to set them (dynamic points of interest - a service for sending users to other users about traffic accidents, traffic police, etc.).

6) Satellite monitoring of transport (service for tracking the movement of the object).

7) Dispatcher (solution for managing your own motor transport / vehicle fleet).

8) Ability to record, view and play tracks (traversed path).

9) Ability to download both own and custom bases of speed tracking cameras.

10) Customizable interface (2D/3D, display of buttons on the navigation screen).

11) Push-to-talk radio, available from the program.

12) «Friends» service, which allows you to display friends, their routes and time of arrival on the map, and also communicate with them using the "Radio" service via the Internet channel.

2. Navitel Navigator - a unique and accurate navigation system that includes a free service «Navitel.Probki», surveillance cameras (SPEEDCAM), a huge database of useful POI objects (gas stations, traffic police, cafes, restaurants, motels, hotels, etc.), the most detailed map of Kazakhstan and transit routes, and settlements in all regions of the country.

System Capabilities:

1) Voice guidance on an automatically routed route.
2) Speed and direction of movement.
3) Coordinates (latitude and longitude, altitude above sea level).
4) Automatic time zone selection.
5) The length of the traversed path, travel time and speed.
6) Recording tracks and waypoints.
7) Export / import of tracks.
8) Export / import routes.
9) Direction of movement to a given point with prediction of time of arrival.
10) Information about the satellites Glonass / GPS.
11) Ability to control the program without a stylus.
12) Voice prompts.
13) Ability to select voice from multiple voice packages and connect your own voice package.
14) Russian-language interface.
15) More than 100 different sensors (on-board computer)
16) Automatic detection of the communication protocol and COM-ports when connecting to the Glonass / GPS-receiver.
17) The ability to automatically turn on/off BlueTooth when connected to Glonass / GPS.
18) Ability to select skin files.

Also at the end of 2014, the company Yandex launched a mobile application for Kazakh drivers to travel around the cities and the country. However, it should be noted that all of the above technologies and programs are focused, first of all, on vehicle drivers and transport companies, and not on meeting the needs of passengers.

In addition, over the past few years, within the framework of the "Smart City" concept, pilot projects of intellectual stop have been implemented in some large cities of Kazakhstan.

So, in the cities of Astana, Uralsk, Taldykorgan, Temirtau and Shchuchinsk, the project of automation of the dispatching service of the city in the management of intraurban traffic and general management of the entire fleet has been implemented. The project is based on the Wialon satellite monitoring system and BusReport software. When implementing this system in Taldykorgan, the municipal government decided to equip the bus stops with special displays simultaneously, which displays the necessary information about the date, the exact time, the air temperature in the city, the time of arrival of each shuttle bus.

In parallel, the InfoBus.kz project, InfoBus.kz, is an information site in which you can find information about public transport in the city, as well as an Android application with similar functionality.

In general, we can recognize that the market of navigation technologies in Kazakhstan is currently not saturated, there are many unoccupied "niches". Acting on the market operators, as a rule, are representatives of foreign companies (Russian, Chinese), and domestic Kazakhstani works on the market are practically not represented.

Comparison of the parameters of the intelligent system with competing developments allows us to conclude that in this market segment there are no analogues of this system. All systems with similar functionality are implemented in the form of websites or applications for smartphones, which greatly narrows the group to their user

As it was said above, there are no direct competitors of the implemented system in the public transport navigation market of Almaty city. Indications of indirect competition are noted by the CityBus system (currently this project is closed). Its main drawback is the requirement for an Internet connection. There is also a terminal from the company GuideJet, which displays only the initial and final public transport stops and the time of its arrival. It does not have the ability to search by routes or sights. It has very limited functionality in comparison with our system.

The key competitive advantages of the developed intelligent stop system are:

- works on any kind of Windows operating system;
- requires a minimum amount of memory;
- reliability;
- ease in expanding systems.

The functional of the system includes:

- providing information on all numbers of routes of various types of public transport to obtain data on how to get from the point of departure (point A) to the destination point (point B);
- providing information on the methods of transplantation from one transport to another;
- providing a search function for the sights of Almaty and ways to reach them the shortest way;

- providing voice support in three languages (Kazakh, Russian, and English), which makes it even easier to use the system for all groups of the population (for example, tourists);
- provision of advertising and news information;
- providing information on the principle of «What's next?» (Organizations, ATMs, restaurants, etc.).
- additional functions that fit into the concept of EXPO-2017: implementation of business processes for the provision of public services for optimization and automation with the development of proposals;
- mediation in the implementation of e-government projects aimed at the provision of public services;
- development of proposals on the formation of a policy of automation of public services in the field of public transport.

2.3.2 System of new developments required for high speed of collection and processing of information on traffic flow. Smooth transition from the «Smart traffic light» to the «Smart City»

The last two decades the term «Smart city» is applied to a family of technologies that can accelerate the development of the city and improve the quality of life in it - this means, for example, the absence of traffic jams and the competent distribution of electricity and government resources.

Such innovations are undoubtedly useful - they seem to grease the gears of a huge city machine, forcing them to spin with a new force. There is no doubt that the ever-increasing amounts of data and the increasing amount of communications will soon change the habitual situation for the urban dweller.

But all the same, what does «Smart city» mean? This term has many definitions, but it is most often used in the meaning of a high-tech city, based on the following elements:

Effective management - a special city telemetry network gives managers access to a single knowledge base that is updated in real time and contains up-to-date information about the actions of city services, the state of the infrastructure and the distribution of electricity flows. Thanks to this knowledge it is possible to control, optimize and improve the ways of using resources. Intellectual software on the basis of the received data also predicts the appearance of possible problems.

Economic development - local companies, having behind them the advanced urban infrastructure, become leaders in the field of advanced technologies and share their experience with all the cities of the world.

Prestige - political leaders want their city to be included in the list of the best - «Smart cities» become an attractive place to do business.

However, some projects of smart cities have gone in the wrong direction: their creators focus only on expensive hardware, forgetting about the ability to use available Internet resources. Very often in this case, interesting technologies are displayed that have nothing to do with the real needs of the city's residents, or empty promises are voiced without any evidence and evidence.

There are several unsuccessful attempts to create a real «Smart city». For example, the eco-city of Masdar in Abu Dhabi, due to advanced technologies, had to minimize carbon dioxide emissions into the atmosphere. There is also the city of Songdo (South Korea) with a huge number of sensors designed to simplify infrastructure management, and the PlanIT Valley in Portugal, which has its own «city operating system». During these projects, it was planned to build a new city from scratch, but none of them went according to plan.

Initiatives to create such cities often emanate from IT companies that know a lot about advanced network technologies and data analysis, but little about how cities are structured - that's why their purpose is often to create a new «peace» rather than struggle with the real problems of already existing cities.

That is why now the concepts of «Smart cities» are unfolding in a slightly different direction. They combine the best modern technologies that use data to identify urban problems, analyze them and solve them together with residents. As in many other areas, technological innovation combines with social innovations - together they are able to achieve much more.

Technology in the service of efficiency.

Successfully developing «Smart cities» of the future will unite in themselves all aspects of the technological infrastructure and use the opportunities of «public technologies». A new set of methods that uses smartphones, the growing popularity of online transactions, low hardware costs and P2P technology, enables municipal authorities to work with citizens to make the best use of resources, collect data and make effective decisions.

Efficiency is the heart of all «Smart cities». To increase it, you can install a huge number of sensors throughout the city and monitor the infrastructure, for example, monitor the condition of the water supply pipes to reduce the number of leaks or the state of affairs on the road so as not to cause congestion.

For example, in Barcelona, a pilot project is currently being tested to equip urban urns and garbage cans with sensors that monitor the level of debris. Thanks to this information, garbage trucks in real time optimize their routes, visiting only those areas in which there are filled urns.

Another example of energy efficiency is a pilot project in Glasgow, where street lights are supplied with sensors that react to movement, so that the lights come on only when people appear on the street. In London, thinking about even larger projects to save electricity - the accelerator Cognicity Challenge, specializing in technologies for «Smart cities», is testing the Demand Logic project, whose goal is to help companies reduce electricity costs through comprehensive monitoring of energy consumption.

An excellent example of the development of the «Smart City» in the RK is the «Electronic Government» system. Smart system for preventing criminal acts and natural disasters. Individual zones of the «Smart City» are monitored in real time. In case of emergencies, the risk and measures of impact in this situation are calculated. The notification of the population about such measures is made automatically through mobile networks, TV channels and the Internet. This makes it possible to ensure the safety of residents.

Collective mind.

To collect data, city authorities can use mobile applications to directly interact with residents, work with companies already collecting data, explore social networks or involve developers of distributed sensor systems. Such methods of data collection are relatively cheap and effective.

Whatever the innovation, based on the involvement of citizens to solve problems, they are based invariably on technologies: sensors, sensors or at least those developments that are already used in modern digital devices such as smartphones or tablets.

In Boston, an experiment was conducted to collect data using the Boston Street Bump application developed by New Urban Mechanics in collaboration with researchers from Boston University. The software created by them uses the mobile phone's accelerometer and records the moment when the vehicle driver runs into the hummock on the road, and then sends the data to the local government.

The application was designed to detect roughness of the road surface, but the obtained data showed that most often these unevenness were «sunken» manhole covers. This helped the city fix 1,250 most serious cases.

To make smart decisions, the government needs to attract a collective mind. Digital technologies give municipal authorities the opportunity to competently allocate city resources, collect data and make decisions, and residents - to report on existing problems. For example, through sensory systems, citizens can assess the condition of residential areas and ask the government to take the necessary measures. What is important is that both the authorities and ordinary people are ready to invest their own resources and resources in the implementation of projects of significance to the city.

Thus, to create a «Smart city» you need the following components:

1. An urban innovation laboratory is needed that investigates digital technologies that would help coordinate the government's actions with the inhabitants of the city. One of the main goals of this laboratory should be to gather information about which of the public technologies are most effective. So far, very few people are engaged in this.
2. The projects of «Smart cities» should be open, it is necessary to involve the public mind of all city residents and small companies.
3. Do not underestimate the behavior of people. The vision of a «Smart city» often misinterprets the role of culture and people's behavior in its functioning. New technologies and data flows will prove beneficial only if they are accompanied by changes in culture.
4. It is necessary to invest not only in «smart» technologies, but also in smart people. The authorities of the city should invest in training to give all personnel of government agencies an understanding of how to work with new data, as well as hire specialized professionals.

5. Nevertheless, «smart» technologies are also necessary: without them it is impossible to develop a «Smart city». It can be projects aimed both at improving the quality of life of specific people (smart home technologies, security systems), and on socially significant initiatives (smart technologies in energy, housing and utilities).

6. It is necessary to bring the possibilities of social technologies to all parts of society. In order for social technologies to work, society should be virtually integrated, but today not everyone has smartphones, Internet access or time to communicate with the government.

Smart transportation. ITS allows the reconstruction of existing road networks through several systematized services: Advanced Traffic Management System (ATMS), Advanced Road User Information System (ATIS), Advanced Public Transport System (APTS), Advanced Vehicle and Motorway Management System (AVHS) and Commercial Vehicle Operation (CVO).

- Central system of traffic management in real time collects and analyzes information on the volume of road traffic, traffic density and speed, generates traffic information through the analysis of various collected data.
- Automatic system of law enforcement. The use of special detectors records the facts of speeding and improper parking of vehicles. The registration number of the vehicle is automatically recognized and all information on the violation is sent to the central data processing center for the issue of a penalty notice.
- Control system of traffic lights in real time. The cycle of traffic lights is adjusted by the system in accordance with changes in road conditions.
- The system of electronic scoreboards on the roads. This solution provides information on road and weather conditions for road users.
- System for collecting video images. This solution provides real-time monitoring of traffic by processing video images
- Parking control system.
- Information system for buses. This system collects and processes information in real time and transmits it to citizens via the Internet or a display system at bus stops. The drivers are given navigational data.
- Electronic payment collection system. The system determines whether the passing vehicle is a participant in the toll road program or not, and electronically collects payment from the accounts of registered motorists without requiring them to stop.
- Measuring the weight of the vehicle while driving
- Parking information system. Here you will find information on the number of vehicles in the parking lot, payment for parking and the way to the free parking space.

3 MODELING OF WORK OF A SMART LIGHTOPHER

3.1 The principle of traffic lights with automatic control.

Conventional traffic lights do not have feedback - they simply change the color of the signals at predetermined intervals. If there is no car along the road crossing the car, then the car on the intersecting road should wait for the green traffic light signal. If there are no pedestrians, then the cars should also stop at the red light. The "smart" traffic light, modeled in this project, saves time for drivers due to the absence of unnecessary expectations.

The project is implemented in the Arduino development environment with Arduino Uno hardware in C/C ++, and the situation is modeled in html and Javascript.

As stated above, the project simulates a crossroads with "smart" traffic lights. "Smart" traffic lights have information on whether there are cars on the road and on which road they are traveling. If there are cars on two intersecting roads, the traffic light operates in the standard mode.

Below is a scheme of an intelligent traffic light based on Arduino (Figure 13):

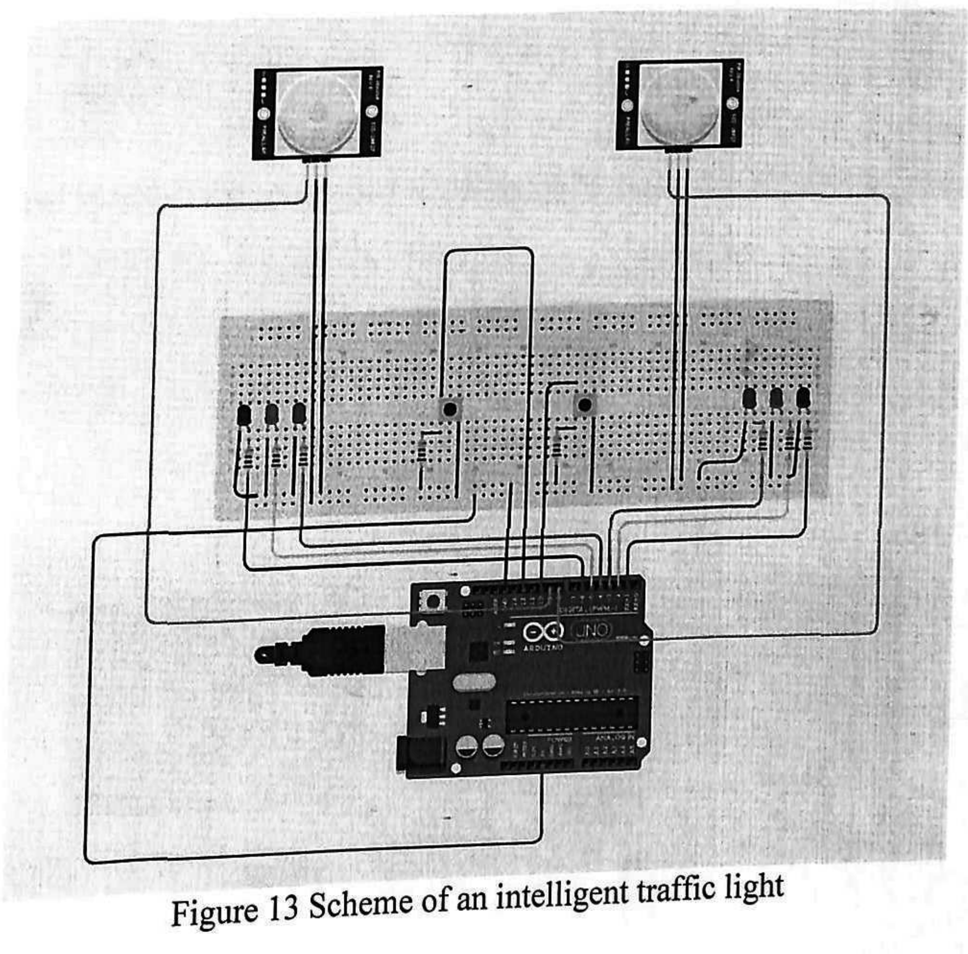

Figure 13 Scheme of an intelligent traffic light

In the daytime, the traffic light switches to normal mode (Figure 14)

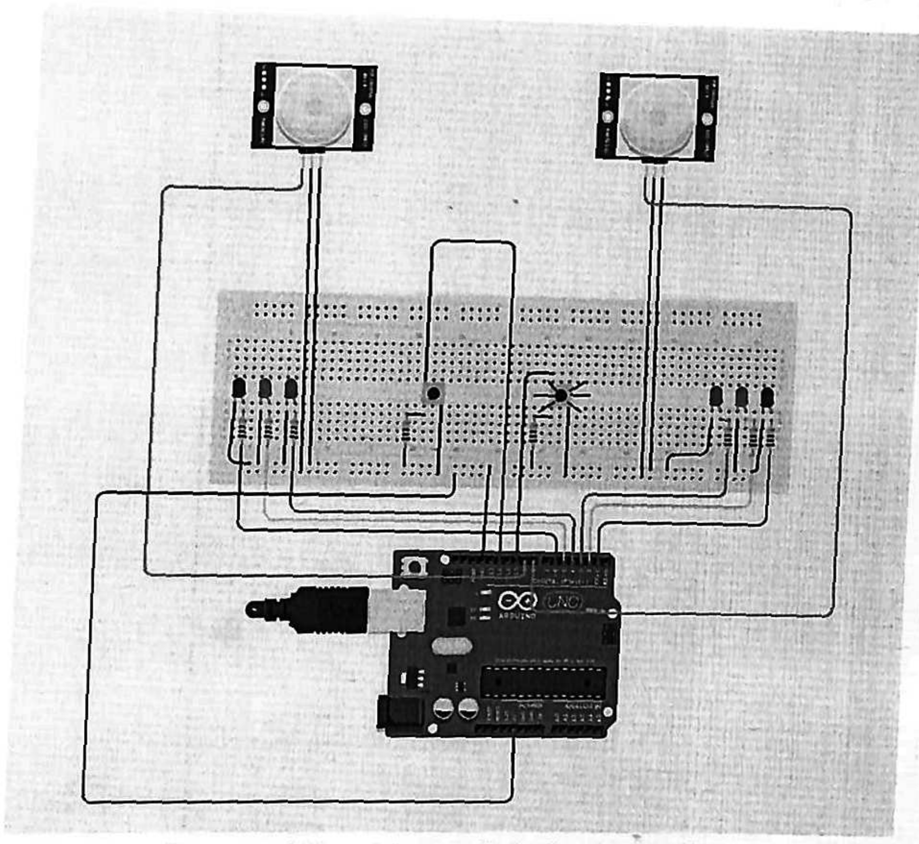

Figure 14 Smart traffic light In the daytime

Figure 15 shows the operation of a traffic light during the daytime (standard mode). The sensors are off at this time.

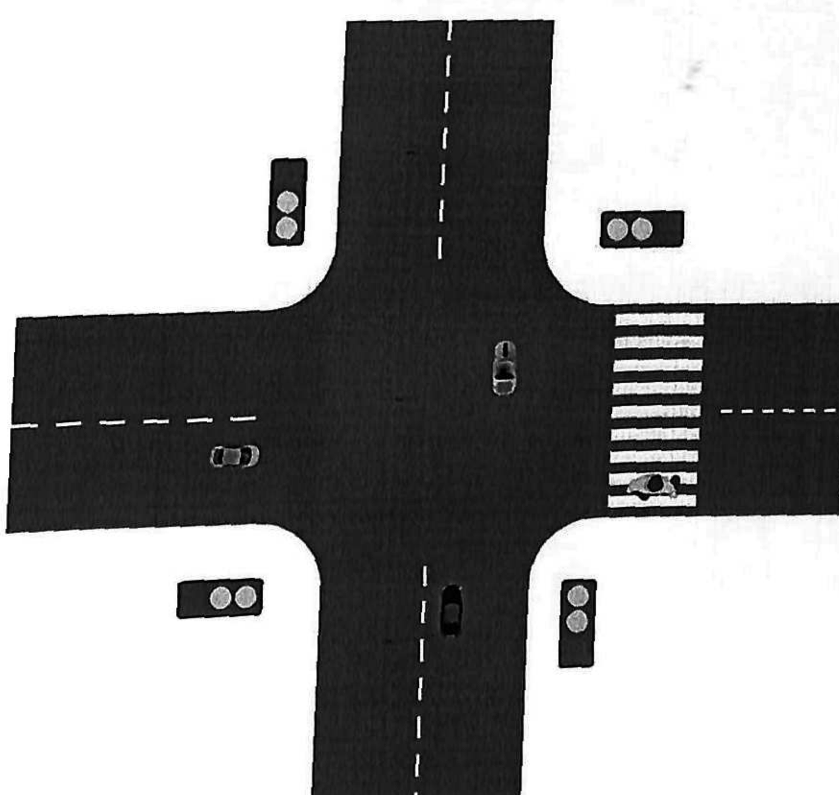

Figure 15 Standard mode of the smart traffic light

Turning the traffic light into night mode (Figure 16).

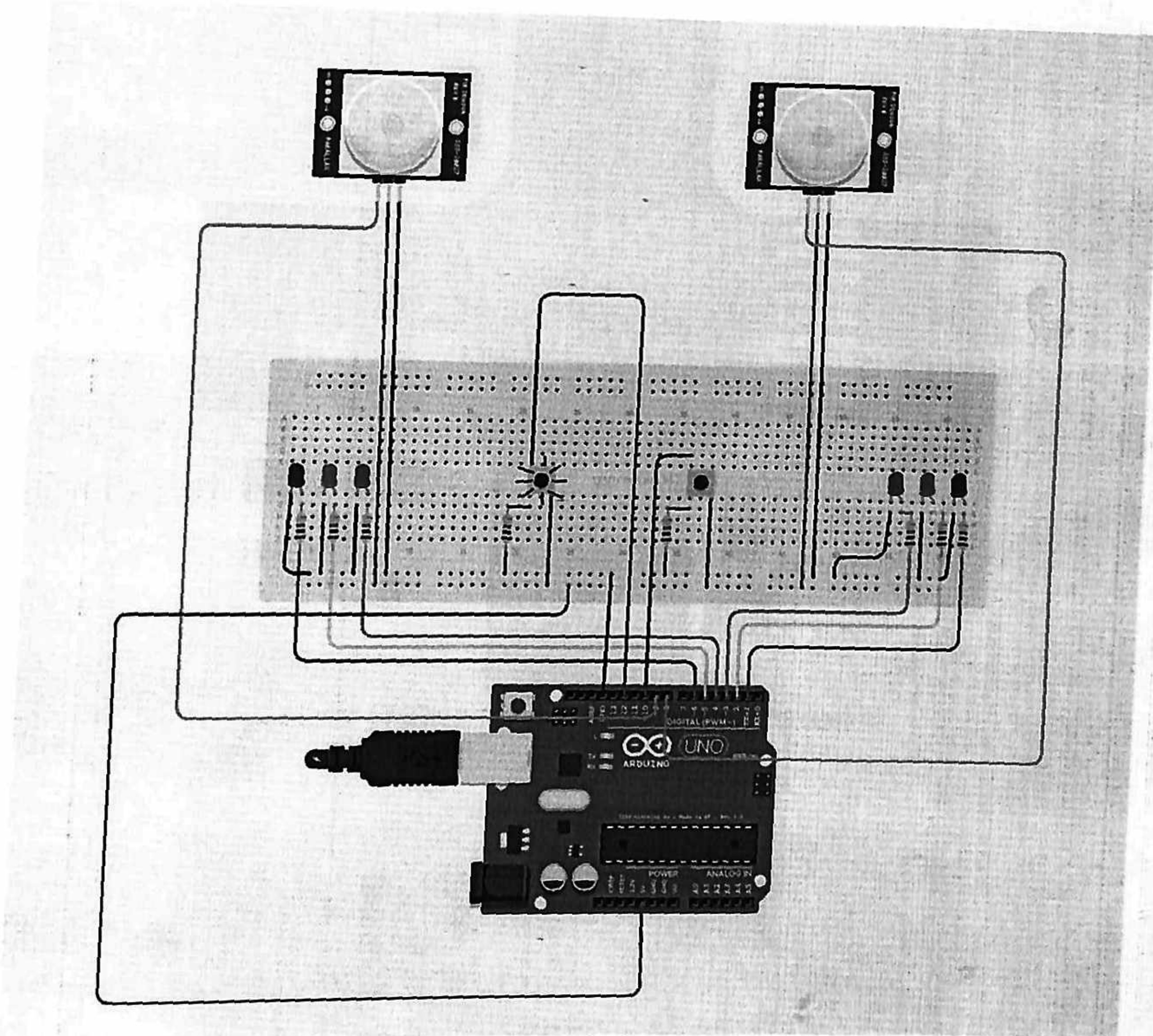

Figure 16 Traffic light in night mode

When the "smart" traffic light switches to night mode, motion sensors are activated which catch the car's movement along the lane and send the received data to the memory. Depending on what road the car goes by, and for what it's not - the traffic light changes the color.

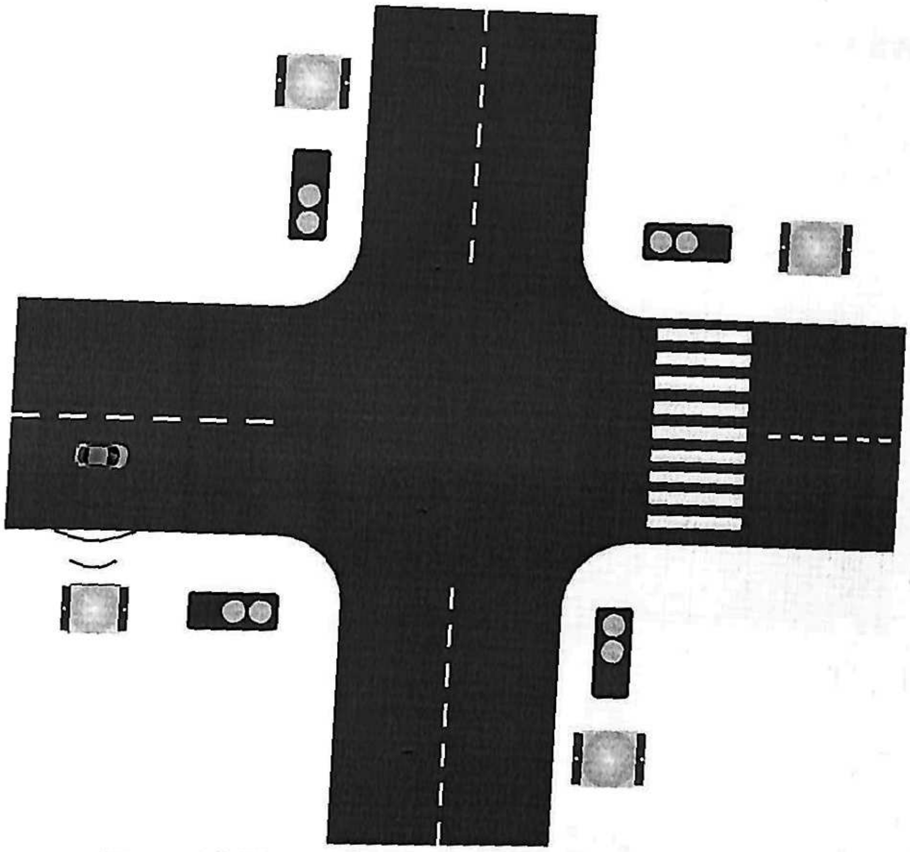

Figure 17 The motion sensor reads the information

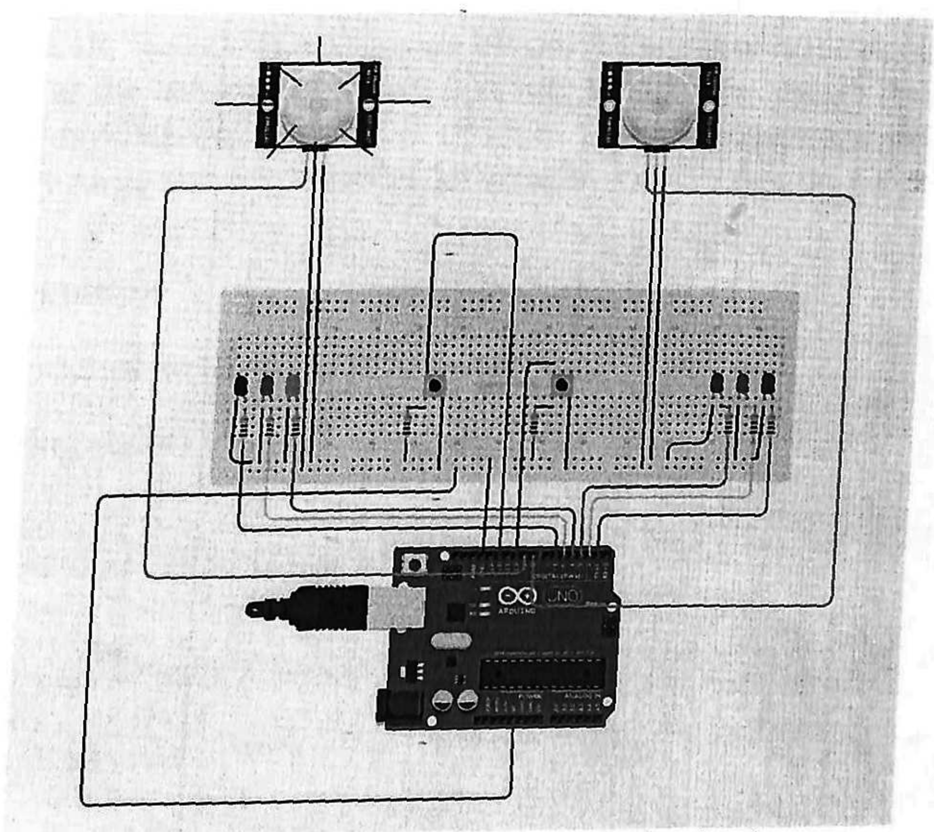

Figure 18 Motion sensor operation in the circuit

After the traffic light has changed its light to green, the car is free and without "unnecessary" expectations continues its journey

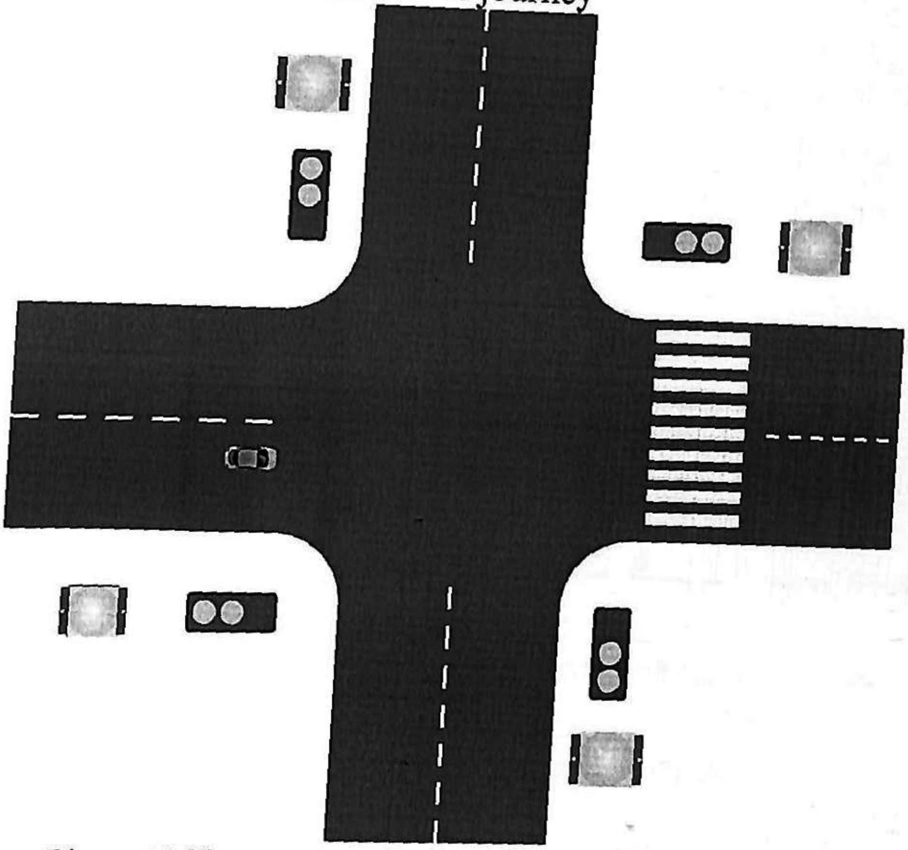

Figure 19 The car passes the intersection without stopping

As a result, the intersection has an inexpensive system that avoids unnecessary expectations at the crossroads. Thus, it is best to use this system mainly at night. Since in the daytime the congestion of roads in such large cities as Almaty and Astana is very large and it will not make sense to use this system not for the day.

3.2 Implementation

Html and Javascript implementation

Importing styles:

```
<head>
    <title>Smart Traffic Light</title>
    <link rel="stylesheet" href="style.css">

    <style type="text/css">
        .box, .too {
            height: 50px;
            width: 50px;
            margin: 1px;
            background-color: black;
            border: solid 1px #000;
            text-align: center;
        }
```

```
    </style>
    <style>
        .signal {
            background-color: #000;
            padding: 5px;
            float: left;
        }

        .signal div {
            list-style: none;
            height: 40px;
            width: 40px;
            border-radius: 50%;
            margin: 4px
```

Main code to switch mode of traffic light:

```
<div class="buttons">

    <button    onclick="switchStatus('A')">Машина    по    дороге
A</button>

    <button    onclick="switchStatus('B')">Машина    по    дороге
Б</button>

    <button onclick="switchStatus(null)">Нет Машин</button>

</div>


<label id="label">Светофор работает в стандартном режиме</label>
```

```
<div id="signal1" class="signal">

    <div></div>

    <div></div>

    <div></div>

</div>
```

Java script code:

```
    <script type='text/javascript'>

        var STATUS = null;

        window.onload = function () {

            var point = 0;
```

```
            var traficLight = function (id, path) {

                var pathLength = path.length;
                var signals = [], i, color, animTimer, element;
                var                          alls                  =
document.getElementById(id).getElementsByTagName('div');

    for  (i = 0; ; i += 1) {
                    color = ['red', 'yellow', 'green'][i % 3];
                    alls[i].style.background = color;
                    signals[color] = alls[i];
                    if (i == 2) break;
                }
                console.log('s', signals)
                var start = function () {
                    if (STATUS == 'A') {
                        point = 0;

                    } else if (STATUS == 'B') {
                        point = 3;
                    } else {
                        point = (point > pathLength - 1) ? 0 :
point;
                    }
                    element = path[point];
                    if (element.interval == 0) {
                        blink(element);
                    } else if (element.dual != '') {
```

```
        signals[element.color].className                         =
signals[element.dual].className = 'active';

                        show(element);

                    } else {

                        signals[element.color].className         =
'active';

                        show(element);

                    }

        point += 1;

                };

                var blink = function (element) {

                    i = 0;

                    animTimer = setInterval(function () {

                        signals[element.color].className          =
(signals[element.color].className == '') ? 'active' : '';

                        if (++i == 6) {

                            clearTimeout(animTimer);

                            start();

                        }

        }, 500);}
                var show = function (element) {

                    animTimer = setInterval(function () {

                        clearTimeout(animTimer);

                        signals[element.color].className = '';

                        if                                 (element.dual)
signals[element.dual].className = '';

                        start();
```

```
                }, element.interval);
            };
            start();};

        var signal = function (color, interval, dual) {
            this.color = color;
            this.interval = interval || 0;
            this.dual = dual || '';
        };
        var red = new signal('red', 5000);
        var redYellow = new signal('red', 2000, 'yellow');
        var yellow = new signal('yellow', 3000);
        var green = new signal('green', 5000);
        var greenBlink = new signal('green');
        var traficLight1 = new traficLight('signal1', [green,
greenBlink, yellow, red, redYellow]);
        function switchStatus(status) {
            STATUS = status;
            var label =  document.getElementById('label');
            if (status == 'A') {
              point = 0;

    label.innerHTML = ('Машина по дороге A');
            } else if(status == 'B'){
                point =3;
                label.innerHTML = ('Машина по дороге B');
            } else {
                label.innerHTML    =    ('Светофор   работает   в
стандартном режиме');
            }}
```

```
            window.switchStatus = switchStatus;
        };
    </script>
```

Arduino (C) Implementation

```
int red = 9;
int yellow = 8;
int green = 7;
int red1 = 12;
int yellow1 = 11;
int green1 = 10;
int inputPin = 2;  // initialization
int pirState = LOW;  // begin programm
int val = 0;
int ledPin = 4;


void setup()
{
  pinMode(ledPin, OUTPUT);
  pinMode(red, OUTPUT);
  pinMode(yellow, OUTPUT);
  pinMode(green, OUTPUT);
  pinMode(red1, OUTPUT);
  pinMode(yellow1, OUTPUT);
  pinMode(green1, OUTPUT);
  pinMode(inputPin, INPUT);  Serial.begin(9600);
}
```

```
void loop()
{
val = digitalRead(inputPin);
if (val == HIGH) {  значение HIGH
      digitalWrite(ledPin, HIGH);
      digitalWrite(green, HIGH);
      digitalWrite(red1, HIGH);
      digitalWrite(green1, LOW);
      digitalWrite(red, LOW);
        if (pirState == LOW) {

                    Serial.println("Motion detected!");
                      pirState = HIGH;
        }
}



else {
      digitalWrite(ledPin, LOW); // выключаем светодиод
      digitalWrite(green1, HIGH);
      digitalWrite(red, HIGH);
      digitalWrite(green, LOW);
      digitalWrite(red1, LOW);
        if (pirState == HIGH){
            Serial.println("Motion ended!");
          pirState = LOW;
        }
}}
```

CONCLUSION

As a result, the management of individual resources and individual departmental standards are referred to the general government and national standards as part of the system.

It is worth noting that, despite the obvious advantages, automatic traffic control systems will not completely solve the problem of traffic jams. The smart traffic light system is only able to maximize the performance of the intersection. At the same time, the city authorities will still have to resort to other means to change the traffic situation of cities. According to analysts, one city strip on average can serve no more than 1800 cars per hour. And this is provided that the vehicles do not stop at intersections and do not face such obstacles as narrowing the road, unsatisfactory quality of the roadway, etc. As the number of cars in our country is steadily growing, it is obvious that even with the maximum productivity of junctions, traffic jams in large megacities will grow, if you only deal with the implementation of «Smart traffic» and not solve other road problems.

REFERENCES

1 Hedlund J. Smart City 2020: Technology and Society in the Modern City // A Microsoft Services Enterprise Architecture Paper. -2012

2 Giffinger R., Fertner C., Kramar H., Kalasek R. Smart cities: ranking of European medium-sized cities // Final report on Smart Cities in Europe. -2007

3 European Commission. Roadmap to a single European transport area resource -towards a competitive and resource efficient transport system // White Paper of European commission. -2011

4 Neirotti P., De Marco A., Gagliano A., Mangano G., Scoranno F. Current Trends in Smart City Initiatives: some stylized facts // Cities. -2014. -Vol. 38. P. 25 - 36

5 Yongmin Z. Interpretation of Smart Planet and Smart City // China Information Times. -2010. –Vol 10. –P 38-41.

6 Cohen B. The Top 10 Smart Cities on the Planet // http://www.fastcoexist.com/1679127/the-top-10-smart-cities-on-the-planet. -2014

7 Smart Cities Seoul: a case study // https://www.itu.int/dms_pub/itu-t/oth/0b/15/T0B150000153301PDFE.pdf.

8 Smart Spotlight: Manuel Cayre // http://amsterdamsmartcity.com/news/detail/id/576/slug/smart-spotlight-manuel-cayr 16 Gurria A. What is a Smart city? Top 5 Smart cities // OECD Environmental outlook to 2050: the consequences of inaction. -2012

9 Smith S. Barcelona named 'Global Smart city – 2015' // Smart cities – System of systems. -2015

10 Buscher V., Doody L. Global Innovators: International case studies on Smart cities // BIS Research Paper. -2013. -Vol 135. -P. 15-17, 45-47

11 Sabha L. Smart cities // Parliament library and reference, research, documentation, and information service. -2014. –Vol. 28. -P. 4

12 Dirks S., Keeling M. A vision of smarter cities: how cities can lead the way into a prosperous and sustainable future // IBM Global Business. -2009

13 Foster M. Building and managing an intelligent city // http://www.fm-house.com/wp-content/uploads/2015/01/Building-Managing-Intelligent-City.pdf. -2011. P. 24 – 25

14 Elise P., Dimitriu S. Smart cities in the making: the importance of a strategic urban agenda for today's Romanian cities // 6 INCD Urban – INCERC / NIR&D conference. – 2013. P. 5

15 Hedlund J. Smart city 2020: technology and society in the modern city // Microsoft Service Enterprise Architecture paper. -2012. -Vol. 1. -P. 12

16 Fenn J., Raskino M. Mastering the hype cycle: how to choose the right innovation at the right time // Hype cycle winners and losers. -2009. P. 14 – 17

17 Giffinger R., Fertner C., Kramar H., Kalasek R., Pichler-Milanovic N., Meijers E. Smart Cities ranking of European medium-sized cities // Final report of Centre of Regional Science in Vienna. -2007. -P.7

18 Haupl M., Vassilakou M. Framework Strategy // Smart City Wien. -2014

19 Perboli G., De Marco A., Perfetti F., and Marone M. A New Taxonomy of Smart City Projects // Proc. of the 17th Meeting of the EURO Working Group on Transportation. -2014. -P. 470-478

20 Vilajosana I. and Dohler M. Machine-to-Machine (M2M) communications for smart cities // Machine-to-Machine (M2M) communications: Architecture, Performance and Applications. -2015. –P. 355-373

21 Ennesser F., Ganem H. Establishing security in machine-to-machine (M2M) communication devices and services // Machine-to-Machine (M2M)

communications: Architecture, Performance and Applications. -2015. –P.227 - 248 32 Kafi M., Challal Y., Djenouri D., Doudou M., Badache N. A study of wireless sensor networks for Urban Traffic Monitoring: Applications and Architectures // Proc. of the 4th International Conference on Ambient Systems, Networks and Technologies. -2013. -Vol. 19. -P. 617- 626
22 Giuffre T., Siniscalchi S., Tesoriere G. A novel architecture of parking management for Smart Cities // Proc. of the 5th International Congress -Sustainability of Road Infrastructures. -2012. -Vol. 53. -P. 16-28
23 Luvisi A., Lorenzini G. RFID-plants in the smart city: Applications and outlook for urban green management // Urban Forestry and Urban Greening. -2014. -Vol.13. -P. 630 - 637