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Development system capacity enhancement and the intersection of software based on the analysis of traffic flow

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ANNOTATION

World car park never stops growing. This process entails transport problems. Mostly, this problem occurs in cities with already established buildings. There has been a rapid increase in transport delays, and a delay leads to congestion, as a consequence.

This process "slows down" the movement of vehicles, as a result there is a decrease in the speed of transports, a considerable over-consumption of fuel, wear of vehicle parts, and an important factor is the deterioration of the ecological situation in the street-road network. Air pollution of our mega-cities is one of the major ills of the big cities in Kazakhstan. Due to the fact that they are too narrow, and even with a lot of crossroads and traffic lights, cars often have to stop, spend hours in traffic.

At each intersection and in the places of congestion, the amount of automobile emissions goes off scale, this occurs under idling and speed dialing modes at this time the maximum volumes of exhaust gases and harmful substances are released into the atmosphere.

From these infromation it is clear that cars especially pollute the air environment by frequent stops and by driving at low speed, mostly at intersections.

Almost all the developed models related to the topic of congestion have a number of limitations, it is difficult to apply for the management of traffic flows in cities. All this led to the need in research, and also confirms the relevance of the chosen topic.

Keywords: car, transport, congestion, throughput, intersection, motorization, highway, road network.

ТҮЙІН

Дүниежүзіндегі автокөлік паркі үнемі өсу үстінде. Бұл процесс көлік проблемаларының туындауына әкеп соғады. Көбінде ол, үлкен ғимараттары бар, ірі мегаполистерге тән қасиет. Автотрафиктің көптігінен және байланыс жылдамдығының төмендеуі нәтижесінде, жол қозғалыстары баяулап, автокептелістер арқасында кезектер туындайды. Жанар-жағар майдың шығыны көбейіп, көлік құрал бөлшектерінің тозуы артады. Осының барлығы көше-жолдарының жүйесінің тозуына, экологиялық жағдайдың нашарлауына әкеп соқтырады.

Қазақстандағы ірі қалалардың көбінде көліктерден тараған зиянды газдардан атмосфералық ауаның ластануы негізгі «бас аруына» айналған. Өйткені олардың көшелері ескі сәулеттік жобалармен салынған. Көшелері тар, қиылыстар мен бағдаршамдардың көптігінен көліктердің тоқтап жүруі жиіленеді, жол жүру ережелері бұзылып, кептелістер көбейеді.

Осыған байланысты қазіргі таңда автокептелістер калалық жерлерде, тасымалдау қозғалысын басқару үшін көптеген қиындықтар туғызып, түрлі шектеулермен жай қозғалыстың нәтижесінде автокөліктерден шыққан зиянды заттар ауаны ластауда.

Қазіргі кезде автокептелістер қалалық жерлерде тасымалдау қозғалысын басқару үшін қиындық келтіруіне байланысты тақырыпқа арналған үлгілер, көптеген шектеулермен ерекшеленеді. Жоғарыда айтылғанның бәрі осы зерттеу жұмысының қажеттілігін туындатып, таңдаған тақырыптың өзектілігін нақтылайды.

Кліттік сөздер:

Автокөлік, тасымалдау, қиылысуы, кептеліс, автотығым, механизация, жол торабы, сыйымдылығы, тасжол.

АННОТАЦИЯ

Мировой парк автомобилей не перестает постоянно увеличиваться. Этот процесс влечет за собой транспортные проблемы. Чаще всего данная проблема возникает в городах с уже сложившейся застройкой. Здесь происходит стремительное увеличение транспортных задержек, «зарождаются» заторы, как следствие, возникают очереди. Этот процесс «тормозит» движение транспортных средств, в результате чего происходит снижение скорости сообщения, значительный перерасход топлива, износ деталей транспортных средств, а еще немало важный фактор ухудшение экологической ситуации на улично-дорожной сети.

Загрязнения атмосферы наших мегаполисов автомобильными выбросами кроется в одной из главных бед крупных городов Казахстана. Из-за того что они слишком узкие, да ещё и с множеством перекрёстков и светофоров, автомобилям приходится часто останавливаться, часами стоять в пробках. На каждом светофоре и в местах образования заторов количество автомобильных выбросов зашкаливает, поскольку при режимах холостого хода и набора скорости в атмосферу выделяются максимальные объёмы выхлопных газов.

Из этих данных следует, что автомобили особенно сильно загрязняют воздушную среду при частых остановках и при движении с малой скоростью, чаще всего это происходит на перекрестках.

Практически все разработанные модели, связанные с тематикой заторов имеют ряд ограничений, трудно применяются для управления транспортными потоками в городах. Все это и привело к необходимости проведения исследования, а также подтверждает актуальность выбранной темы.

Ключевые слова: автомобиль, транспорт, затор, пробка, пропускная способность, перекресток, автомобилизация, улично-дорожная сеть, магистраль.

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INTRODUCTION

In Kazakhstan, congestion occurs due to low road capacity; Disorderly parking of vehicles on the carriageway; Set of traffic lights and time wasting while waiting for their switching; Lack of pedestrian lanes and indiscriminate street crossing by pedestrians; Unpopularity of public transport; Culture of drivers, lack of mutual respect; Disorderly movement of special equipment and heavy vehicles; Unregulated 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 motorists to rebuild at very low speed).

The exits 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 goes off scale, since under idling and speed dialing conditions, maximum 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, even if the left row is even more free, as it approaches the intersection it stops moving, because not every intersection has a traffic light with an additional arrow, and as a result, in one period Turn on average only 3-4 cars.

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 occupy a whole lane and significantly reduce the throughput of the intersection.

To solve these problems, it is enough to prohibit the left turn at the intersection and let the entire flow of vehicles to the right and forward, so that after driving to the gap in the dividing strip wherever they turn left, you can speed up the flow of cars and keep the whole lane.

1 CORK CONDITION OF TRAFFIC FLOWS

1.1 Basic concepts of congestion

To date, there is no general concept of "congestion". 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 congestion.

And if the cycle of traffic light regulation is 90 seconds and the driver of the vehicle should wait for his turn on the road through the intersection of 3-5 cycles, this phenomenon can be called pre-congestion.

Being in front of the intersection for more than 7.5 minutes, the driver of the vehicle is in a harsh situation . In the expert dictionary - auto technology, the concept of traffic congestion is interpreted as a delay in the movement of vehicles, caused by a significant reduction in the capacity of a section of the road network.

The congestion occurs at a time when the intensity of arriving vehicles on this section of the road exceeds the capacity of this section.

With an increase in density exceeding the capacity, the flow rate drops to zero, which corresponds to the congestion.

The term "traffic congestion" is used in the traffic rules. It states that "it is forbidden to go to the intersection or the intersection of carriageways, if there is a congestion that will force the driver to stop, creating an obstacle to the movement of the vehicle in the transverse direction".

Summarizing all the interpretations, it is possible to interpret "congestion" as a road situation that causes the driver to stop, contrary to his desire to continue moving, with the regulating mode permitting this movement.

In fact, not strict concepts on the term "congestion" are used, as a rule, use obvious concepts that allow one to give subjective vague estimates of this phenomenon.

The uncertainty of the criteria for this phenomenon partly explains the uncertainty and ineffectiveness of the management impacts on road traffic in order to prevent, detect and eliminate congestion [1].

As a rule, congestion is a negative phenomenon that appears as a result of the impossibility of changing the geometric parameters of road network, as well as increasing the intensity of movement. As soon as there is an increase in density and a drop in speed (close to zero) - the operation of the road network becomes completely inefficient (Figure 1).

Figure 1. Traffic jam

Researchers in the field believe that as soon as the value of the traffic flow intensity approaches the capacity value, the congestion will continue to spread, and as a consequence, the "paralysis" of the street-road network occurs. [6]

It is known that when there are congestion in the traffic, the participants of the movement have nervousness, fatigue and irritability. This has a negative effect on the accident rate.

1.2 Causes of congestion

1.2.1 The influence of the growth of motorization on the occurrence of congestion

The degree of saturation of the country with transports, which is defined as the number of all vehicles per thousand inhabitants is called the indicator of motorization. However, the most often used indicator of motorization, determined by the number of cars per 1,000 people (Diagram 1). Practically in all countries the park of cars constantly grows.

According to the database of the Ministry of Internal Affairs of the Republic of Kazakhstan as of March 1, 2017, 4,425,770 vehicles are registered in the state register. Thus, there are 250 cars per 1,000 people. Annually, about 540-570 thousand driving licenses are issued. In 2016, 563 thousand 956 certificates were issued, including 194 thousand 559 people for the first time.

At the same time, officially in Kazakhstan, 3 million 845 thousand 301 cars were registered. The population of Kazakhstan in 2016 approached 18 million people.

In 2000, the number of transport in the country did not exceed 1.3 million. Of these, cars were 1 million 298 units. Then 14.8 million citizens were registered in Kazakhstan. The level of motorization was 88 cars per 1000 people.

In 2010, the level of motorization in Kazakhstan was 189 cars per 1,000 residents of the country with a population of 16.3 million people.

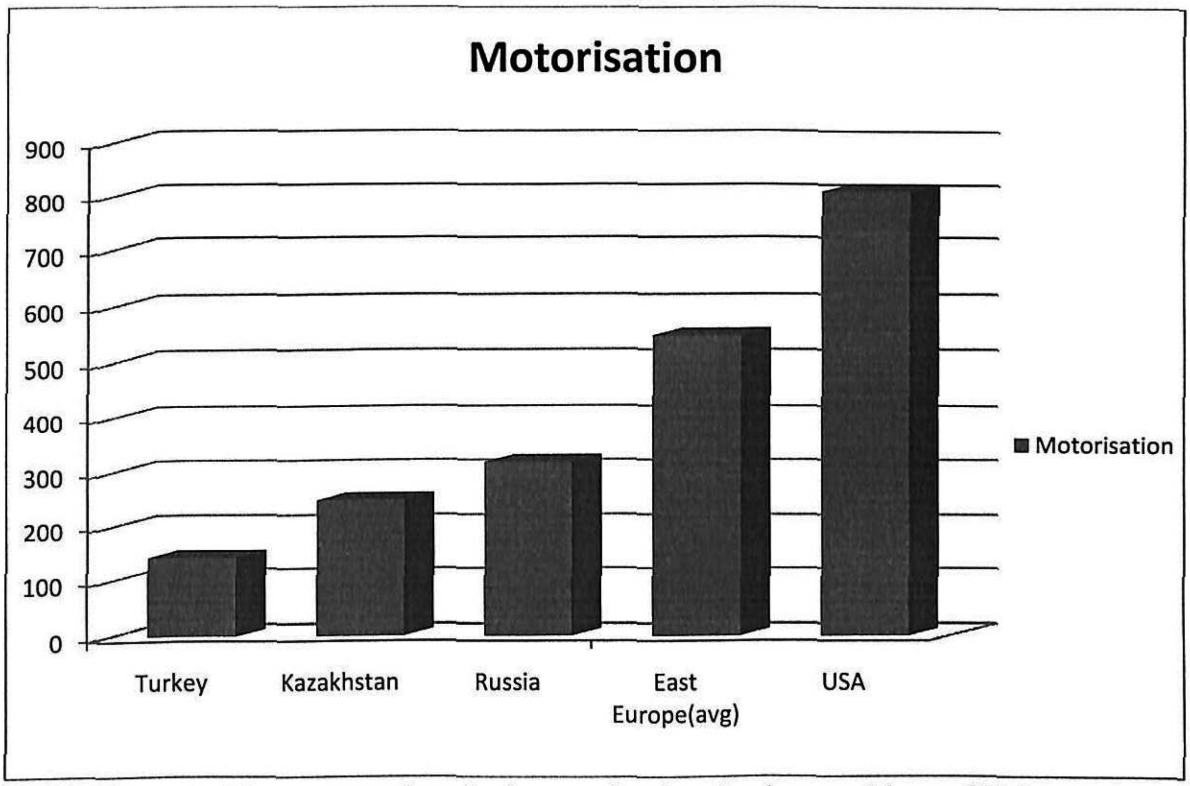

Diagram 1. The current level of motorization in the world as of February-March 2017 (passenger cars per 1000 people)

Motorization includes directly as a positive impact on social development and economic benefits, as well as negative aspects, such as a significant number of road accidents, wounded, dead, significant damage caused not only to citizens, but to the state as a whole. Also, this indicator adversely affects the environment, especially when located in the ground state [4].

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 319 [7].

Table 1

Level of motorization in the subjects of the Republic of Kazakhstan

Subject name	2000	2005	2010	2013	2016
	Level of motorization, auto / 1000 people.				
Almaty	138	158	239	284	342
Astana	101	147	212	270	311
North Kazakhstan region	93	112	180	225	263
Kyzylorda Region	66	89	106	121	143
Country average	91	127	189	210	230
Increase in the average in relation to 2000	-	1,4	2,1	2,3	2,5

Statistics of the level of motorization in the subjects of Kazakhstan are presented in Figure 2.

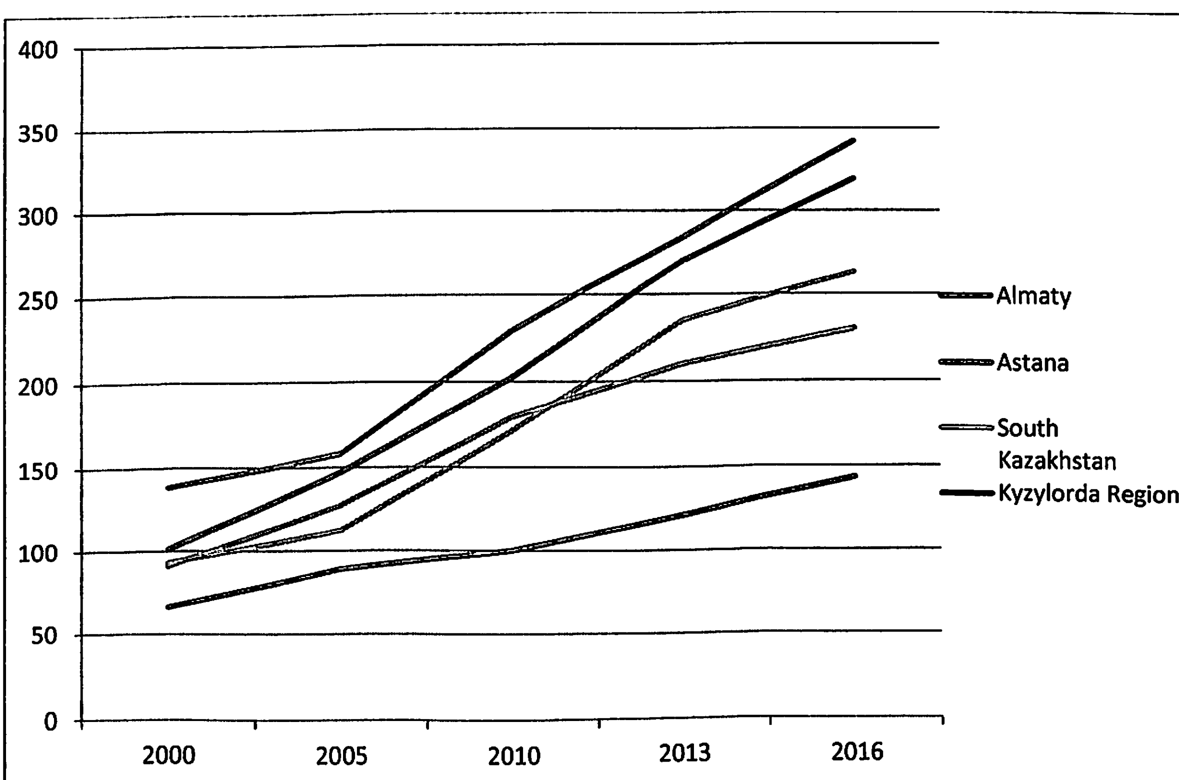

Figure 2. The level of motorization from 2000 to 2016

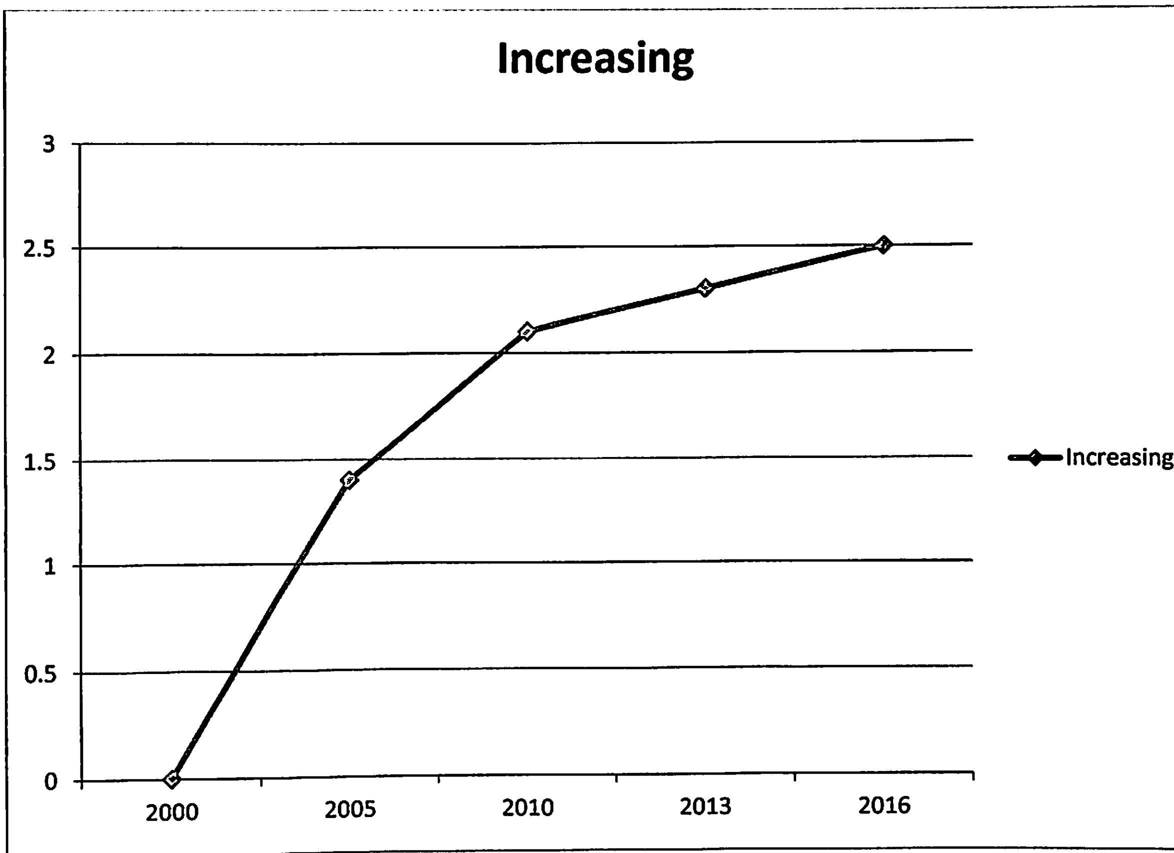

Figure 3. Increase in the level of motorization in relation to 2000

Even according to Kazakh standards, the Southern capital is not the most motorized city in the country, in which the population grows faster than the car park.

On the other hand, there are a lot of new cars from other regions in Almaty. The lowest density of cars in the Kyzylorda region is 143 cars.

Recently, there has been a strong growth in the automotive industry and an increase in demand for its products in the Republic of Kazakhstan, as a result of which the number of vehicles on the roads of Kazakhstan is significantly increasing.

However, measures to reduce the number of accidents do not make a significant adjustment. The Government and the State Traffic Safety Inspectorate of the Republic of Kazakhstan find it difficult to correct this situation by applying many different methods.

1.2.2 Influence of geometric parameters Road traffic network is the formation of congestion

Street-road network is a collection of streets and roads in a single transport system of the city. Street and road network of the city, geometric and structural parameters largely depend on some factors, such as population density, city planning structure, traffic flow composition, loading level of road network sections, as a consequence, the speed of cars in these sections, concentration and distribution of pedestrian flows. Historical urban planning was not designed for the current situation on the street road network. Significant changes in the speed and traffic intensity of the vehicle, as well as the dynamic characteristics of the vehicle, led to the formation of a deficit in the area of the carriageway and an increase in the requirements for the organization of traffic and technical facilities. The discrepancy between the level of development of motorization and the level of development of the street road network leads to the creation of inconvenience to the movement of the population of cities, significant economic losses in transport, a decrease in the level of traffic safety, and an increase in the negative impact on the environment.

The old street road network had to be prepared for the fast-growing traffic flows that were formed as a result of the rapid pace of motorization indicators. At the same time, all the disadvantages of the inadequate street road network immediately appeared:

- the appearance of the vehicle on the existing carriageway, which moved more than 10 times faster than the pedestrian flow, while conflict situations developed;
- transport networks for the movement of route transport were built at the points of attraction, i.e. in those places where there was a large number of real passengers, i.e. along the main streets. These lines attracted even more potential - pedestrians, going to and from stops. In this case, there has been an increase in conflicts;
- arrangements for the preparation of the existing street road network for the improvement of schemes (the arrangement of dividing strips, the reconstruction of the carriageway, the arrangement of pavement paths, etc.) were only part of the positive effect, thus creating only additional questions in improving the efficiency of the street network (construction of pedestrian crossings). In general, the existing problems were not solved.

In essence, it was necessary to adapt existing street networks not only to old buildings, but also new ones. First of all, the faces were oriented not only to shops and shopping centers, but also to residential buildings.

This situation again served as a source of causing transport conflicts between cars and people.

The process of changing the functions of streets for the cities of North America and Western Europe is very characteristic. In the 1960s and 1970s, in the city of Graz (Austria), as a result of the growth in the number of individual vehicles, 28% of tram lines were provided, a significant part of the sidewalks was used for parking. In the current situation, the danger of pedestrian movements and bicycle rides increased.

In connection with the awareness of the need to preserve the environment and the undesirability of increasing conflicts, it became necessary to create new town-planning solutions. Progressive features of the formation of the street road network were aimed at reducing conflict points. As a result:

1) the separation of the street road network according to the type of traffic, as well as the separation of vehicles and pedestrian flows;

2) street road networks, which are intended for traffic flow, having an increased speed are similar to transport highways;

3) there is a similarity with the parameters of the mains (construction of highways passing through the city);

4) lack of connection between residential buildings and highways;

5) carrying out the registration of provisions on environmental protection for the construction of a road network.

The road network is one of the most important elements of the transport system of any region. Observing the development level of the street road network, it is possible to assess the overall economic development of the territory. The broadening of the road network has a significant impact on the stabilization of the socio-economic situation in the country.

Thus, the development of the transport system is one of the important factors that stimulate the social and economic development of the city and helps reduce the occurrence of traffic jams.

The decisive influence on the characteristics of the traffic flow, as well as the state of traffic in urban areas is provided by geometric and planning configurations of the communication routes. Transport communications historically developed on the basis of city streets and country roads, which were intended to a greater extent for the movement of cartage transport. In the early twentieth century, reconstruction of selected sections of the street network was carried out. Initially, the construction of streets and roads designed for vehicles with large axle loads and high speed regimes was carried out in the United States, and then in other countries, which included the CIS countries. At the moment, some roads do not meet modern requirements [19, 8].

Streets and country roads must meet the requirements of the building codes and regulations of the Republic of Kazakhstan. In this case, safe conditions for the movement of the Transports will be created. For the creation of safe conditions, the following characteristics are of significant importance: the density of the road network, the density of residential development, the distance from the centers of attraction to the peripheral points of destination, the coefficient of the non-rectilinearity of the street road network, which characterizes the ratio of the length of the route to the minimum distance for travel [9].

Road safety is affected by increased traffic flow and pedestrian flow. According to statistics, a large number of accidents occur in cities and towns (about 70%). In the urban traffic, intersections are places of concentration of a large number of accidents. Thus, intersections need to be given special attention in terms of road safety [10].

Safe and efficient functioning of the street road network of the settlement should be composed of the interests of road users, using a system of complexes for traffic management and territory planning.

At the same time, it is important to take into account the social and environmental functions of streets and squares, the availability of plots for public transport, pedestrians and cyclists, at the same time taking into account the interests of people with disabilities.

1.2.3 Interrelation of urban planning scheme and congestion of road network

Planning schemes of the street road network significantly affect the main traffic indicators, as well as the organization of passenger traffic and the solution of traffic management problems.

The layout of the street road network can have very diverse contours. It is necessary that this scheme is clear and easy to build, do not allow the mutual imposition of traffic flows due to the merger of various road network in separate areas. It should include the ability to distribute traffic flows, as well as prevent the transit traffic of external transport through the entire city and the movement of urban traffic flows through the central part of the city.

Distinguish the following types of street road network, depending on the planning scheme: radial, rational-circular, rectangular, rectangular-diagonal, combined.

In most cases, in cities with historically developed buildings (more than 500 years), in which radial directions pass to suburban roads, a radial scheme is used (Figure 5, a). When organizing such a scheme, communication of peripheral regions with the city center is ensured, but there is a negative consequence - the overload of the central part of the city is inevitable and communication between peripheral regions is difficult. The radial scheme can be used for small cities. In the conditions of modern transport requirements in other cities, this scheme in its pure form is inexpedient. In order to increase the capacity of the street road network of cities, it is necessary to arrange bypass roads around them, connecting the city center with its outskirts. This will get rid of the existing shortcomings. In this case, this layout is radial-circular.

Radial-annular (Figure 5, b) scheme is the development of a radial scheme using circular lines. The data of the highway free the central part of the city from the load and provide more free connections between the peripheral areas of the city.

Rectangular scheme (Figure 5, c) can be found in young cities, the development of which occurred according to well-designed plans. The positive side of this scheme is its simplicity, high throughput, the ability to distribute traffic across parallel streets of the city, the lack of a single transport hub. The absence of a pronounced center and the presence of parallel roads is inherent in a rectangular street network scheme. The movement of the cross-flow in this case is uniform. The drawbacks of the scheme include the difficulty of the connections between the peripheral points.

Diagonal trunks that connect the most remote points between them are envisaged to eliminate the above-mentioned shortcoming, while the street-road network scheme assumes a rectangular-diagonal structure. The disadvantage of the rectangular scheme is the considerable distance of the opposite peripheral regions.

Further development of the rectangular scheme is a rectangular-diagonal scheme (Figure 5, d). To simplify communication between peripheral regions between themselves and the center, diagonal lines are used. The drawbacks of this scheme include the presence of nodes with many incoming streets, including at an angle, which greatly complicates the movement of transport along them. The street network of the city of Detroit is an example of such schemes [11].

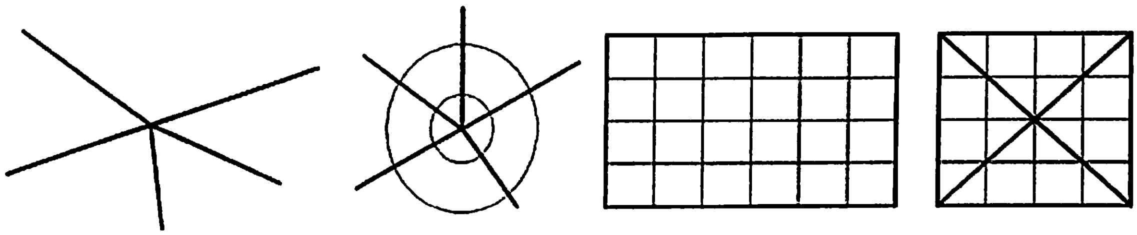

Figure 5. Geometric schemes of the street road network: a) radial scheme; B) radially annular; C) rectangular; D) rectangular-diagonal

Thus, it is very important when designing cities to correctly choose the geometric scheme of the street road network, so that in the future not to meet with congestion arising from the rapid growth of motorization.

1.2.4 Influence of various factors on the speed of the traffic flow

The following factors affect the speed of the traffic flow:

- driver
- type of vehicle
- type and condition of the road
- traffic intensity
- the environment, etc.

It is known that the driver's gender and the presence of passengers in the vehicle do not have a significant impact on the speed of the traffic flow. However, single drivers tend to move at a faster rate than drivers with passengers. Dangerous speeds are more frequent for men than for women [1]. The type of car influences the speed much more than the driver factor. In our region on the intercity road, cars usually travel at a speed of 110-120 km/h, exceeding the permitted speed of 90 km/h.

Trucks with cargo move at a speed of 80 km / h, without cargo - 90-100 km / h.

The speed of cars is significantly affected by the type and condition of the road, curvature, ups and downs, the number of strips, the type of cover, the distance of visibility,

Estimates of street traffic congestion by source of occurrence are useful for guiding the research program of the Federal Highway Administration of the United States of America, and based on the results of the study, it is possible to identify which most important reasons should be identified as a percentage (Figure 6) [22].

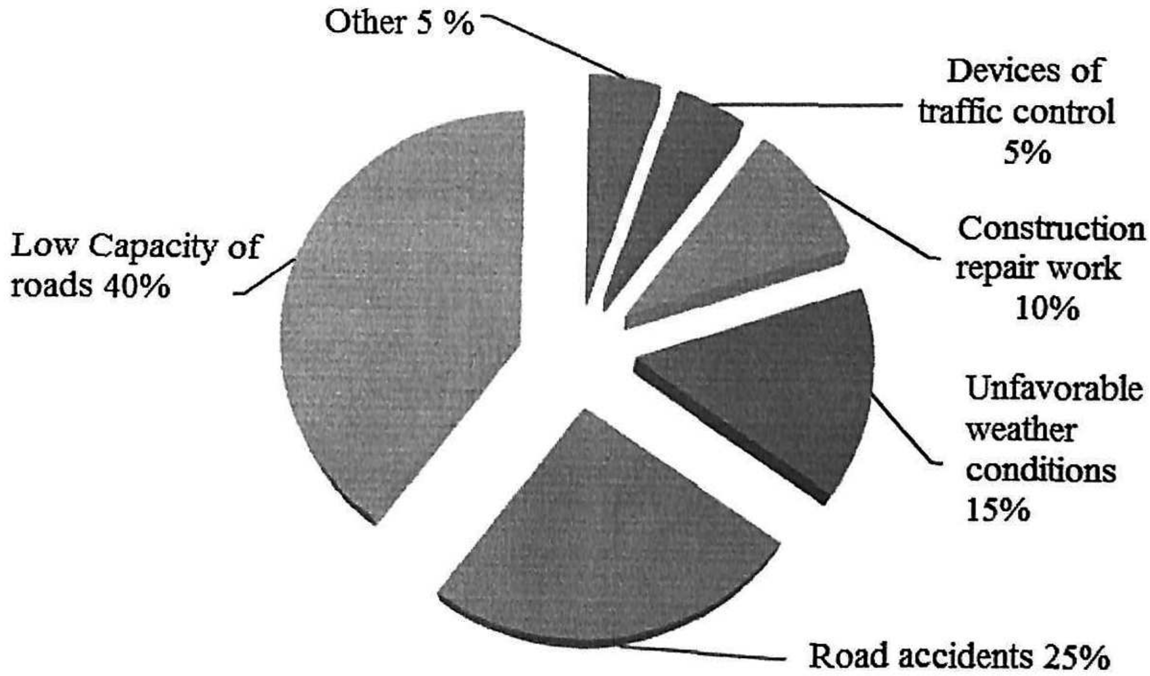

Figure 6. Probability of major causes of transport delay as a percentage

On highways in good condition, the speed of movement is determined by the geometry of the elements of these roads. Thus, the speed depends on the road category.

In urban conditions, the speed depends on the traffic intensity, traffic signs, controls and interference to traffic. On city roads, the speed is less than on intercity roads. The average speed on an adjustable, city road with high traffic intensity rarely exceeds 35 km / h. On an unregulated, city road with high traffic intensity, the speed is from 35 to 50 km / h, and on the expressway - 64-97 km / h.

When the car moves along the curve in the road map, the average speed decreases and is 80-85% of the limiting speed calculated for the clutch.

The reference [1] gives an empirical formula:

$$V=75-1220\times K; \qquad (1.1)$$

Where V - speed a / m, km / h; K = 1 / Rn is the curvature, 1 / km; Rn is the radius of rotation.

In the formula, the speed of rectilinear motion is 75 km / h.

When moving simultaneously on the rise and along the curve, the decrease in the speed V, km / h can be calculated approximately by formula (1.2):

$$V=75-1220\times 1{,}37\gamma; \qquad (1.2)$$

Where K is the turning radius, 1 / km;

γ – angle of ascent, %.

The speed of the car depends on the location of the lane on the road. For example, on a three-lane road the highest average speed is observed on the middle lane. On the far right lane trucks are moving, which reduces the speed of other cars. On this strip, the flow velocity is equal to the speed of the trucks. On the left-most lane, the speed depends on the presence of intersections on which cars perform turns, interfering with traffic.

Figure 7 shows the distribution of speeds on a four-lane, long-distance road. The graphs show the accumulated frequency.

Experimental data were obtained by Shevyakov A.P. [2].

Different authors use different notations to denote different parameters of the transport stream, which introduces some difficulties in the classification of notations. In this chapter, devoted to the analysis of existing methods for estimating the delays in traffic on the road network, the parameters of the traffic flow are indicated by those letters that are indicated in the original sources. However, in the future, all the parameters of the transport stream are systematized in accordance with the common notations, the most common in Kazakhstan (N is the traffic flow, V is the speed of the traffic flow, and q is the traffic flow density).

On the right, extreme lane 1 (see Figure 7) heavy trucks move with an average speed of 48 km / h. On the right lane 2 trucks are moving at an average speed of 60 km / h. In lane 3, cars with an average speed of 70 km / h are moving. In strip 4, high-speed cars are moving at an average speed of 93 km / h.

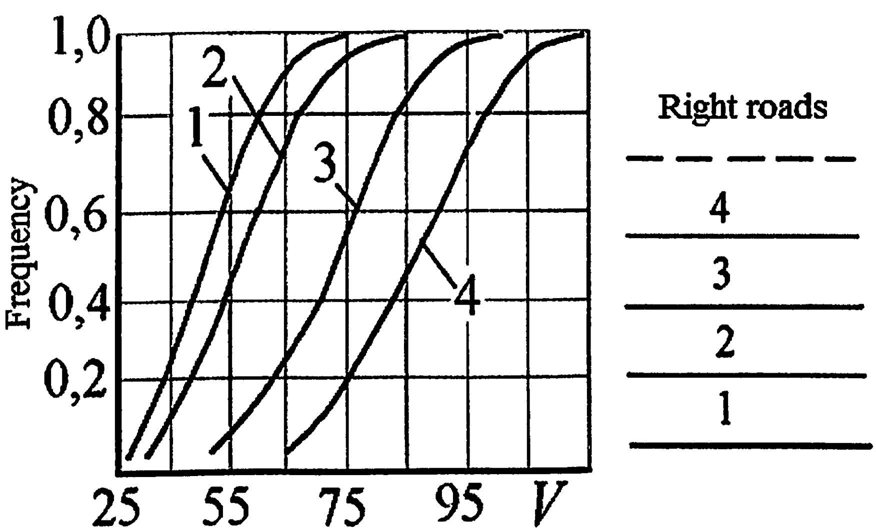

Figure 7. Distribution of speeds on a four-lane road, average speeds:
1 - 48 km / h, 2 - 60 km / h, 3 - 70 km / h, 4 - 93 km / h [2]

The speed of movement of cars depends on the width of the lane. If the band has restrictions, the speed of the traffic flow is reduced by 2-5 km / h. Restrictions are created by road restrictions, standing vehicles, etc.

When the intensity of the flow increases, the speed of movement decreases. In Figure 8 we see the effect of intensity obtained in the USA on a horizontal road without restrictive signs and traffic lights [3]. At high intensity 1100 auth / h the saturation of the flow is achieved, and the speed of the transport stream is reduced to the minimum value, practically independent of other factors. The flow velocity is usually related to its density by a linear dependence (Figure 9). The average value of the velocity corresponds to a critical density, which is approximately equal to half the maximum density [1].

The speed of cars depends on the conditions for overtaking. Usually, overtaking is performed if the speed of the overtaking and overtaking vehicle is 16 km / h. The overtaking vehicle moves at an average speed of 10 km / h higher than the flow rate.

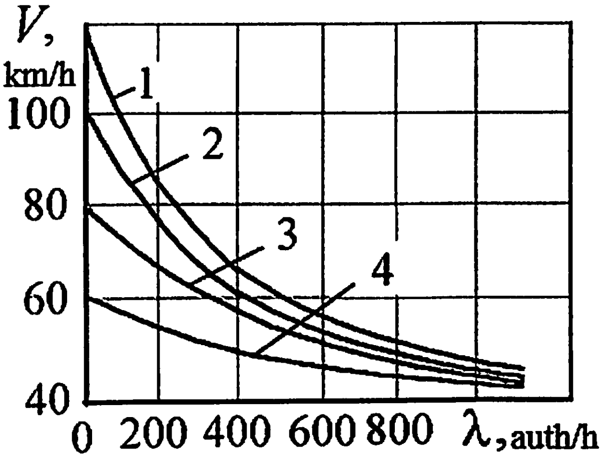

Figure 8. Dependence of the speed of the traffic flow on the traffic at the initial speed: 1 - 120 km / h, 2 - 100 km / h, 3 - 80 km / h, 4 - 60 km / h [2]

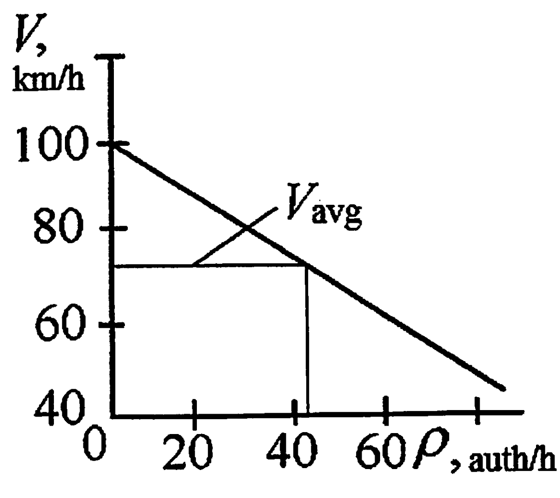

Figure 9. The dependence of the transport flow velocity on the density [2]

Speed depends on time of day and weather. On average, on a city road, the speed of a car is 2 km / h in the daytime more than in the evening, on a country road - by 8 km / h. In the rain, the speed drops by 7-23%, with poor visibility by 4-38%, with simultaneous rain and reduced visibility by 10-50%.

In order to take into account the simultaneous influence of factors, special studies were carried out. Based on the results of the research, regression formulas were obtained.

Influence of various factors on the intensity of the traffic flow.

In rural areas there is a low intensity of traffic, it is less than 1000 cars / day (42 cars / hour). On the majority of city roads, the average traffic intensity is 4000 cars / day (170 cars / h, 64% of roads). On busy urban roads there is a high traffic intensity of 10,000 cars / day (420 cars / hour) and more.

The change in intensity during the year is subject to certain regularities. Almost on all roads the greatest intensity is reached in the summer and autumn periods. In Figure 10 shows the distribution of intensity by the months of the year [4] on unloaded roads.

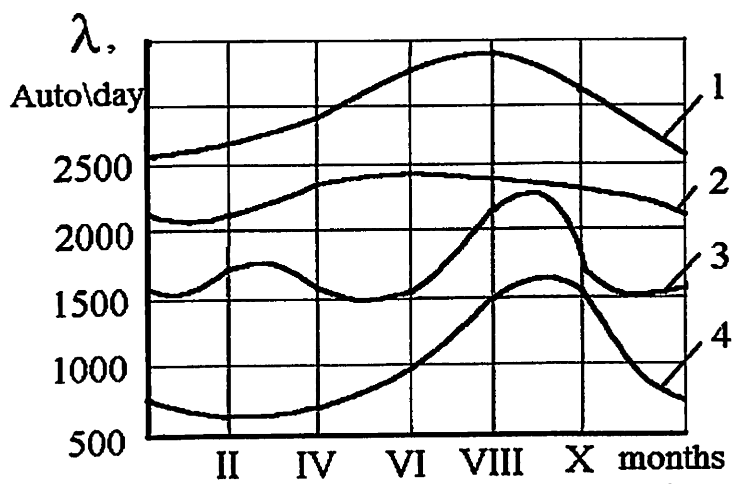

Figure 10 - Change in traffic intensity during the year on the roads: 1 - in the suburban area of megacities; 2 - in industrial areas of the city; 3 - in agricultural areas; 4 - in the resort area [4]

The intensity of movement depends on the day of the week. According to [1], the highest intensity is observed on Friday (Figure 11). It reaches 125% of the average daily intensity. The lowest intensity of movement takes place on Sunday (72%).

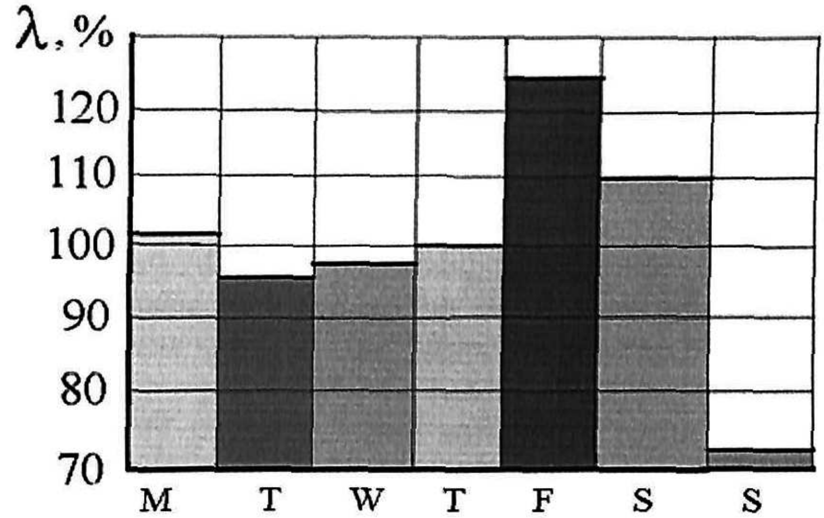

Figure 11 - Change in traffic intensity during the week as a percentage of its average value [4]

1.2.5 Methods for improving the performance of the road network

The growth of motorization and the lag in the development of the infrastructure of the street road network in modern cities lead to transport problems related to the increase in the level of loading, the increase in the number of places for the concentration of accidents, the deterioration of the environmental situation in the allotment bands. These factors lead to the inevitable occurrence of harsh phenomena and indicate the need to take measures to prevent the above factors. The transport problem can be solved with the help of architectural and planning activities and a set of organizational approaches.

Activities related to the construction of infrastructure are quite expensive and in cases of historically developed buildings are not applicable. In this case, it is necessary to use progressive organizational approaches based on the modeling of the Transport flow and transport processes, as well as the use of modern technologies and technical means of organizing traffic, based on information and complete automation of traffic flow control.

In the scientific field of transport systems, many studies of domestic and foreign scientists are aimed at improving the efficiency of traffic light facilities [6] and eliminating the existing problems of Traffic flow on the street network [19].

An important problem that constantly appears on the streets of the road network is the occurrence of regular traffic congestion. The problem of the formation of focal phenomena is considered in the study[19].

To solve the existing problem of the constantly arising torrential phenomena, many authors suggest methods of "fighting" with regular congestion. These include: the reconstruction of sections of the road network, the optimization of traffic signal regulation, the construction of multi-level interchanges, etc.

It should be noted that many considered methods shown in the classification structure are formed on the criteria of effectiveness evaluation, which in certain cases contradict one another. Increasing the speed of traffic can reduce delays in the way, reduce the number of emissions of harmful substances, but this increases the risk of an accident.

The capacity of the road is an important transport characteristic in the organization of traffic, which makes it possible to determine the efficiency of the functioning of the street road network. In theory and practice in the field of traffic management, special attention is paid to increasing the carrying capacity of the street road network. This is an urgent task of organizing traffic.

To increase the traffic capacity of the street road network, the following measures should be applied: changing the geometric scheme of the street network, building multi-level interchanges and bypass roads, organizing an organized parking space, increasing the speed regime in some sections of roads, developing optimal modes of operation of a traffic light facility. All this contributes to improving the quality of traffic and improving the safety of road users.

Thus, at the stage of designing the main ones and taking into account the existing elements of the street road network of cities, the methods used in planning the street road network of cities are defined. The methods that determine the throughput are based on different approaches. There are methods based, in particular, on modeling the transport flow. In this connection, the data obtained as a result of modeling may differ. In such cases, it is necessary to check the adequacy of the model for reliability.

An overview of Section 1.2.5 shows that all the methods presented have their drawbacks. As a result of the research it was found that the obvious cause of congestion is an increased level of motorization, and as a result, an increase in the level of loading of the street road network. Organizational methods sufficiently allow to solve questions on increasing the effectiveness of the organization of the movement.

1.3 Consequences from congestion

1.3.1 Deteriorating environmental conditions in cities

The 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 auth/h, the noise level rises by 10 dBA. This indicator also has a dependence on the speed of the traffic flow [4].

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 of lead oxides.

An important problem of the deterioration of the environment is the smoke of cars.

Causes, car smoke different engine malfunction, unreasonable power 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. Badly inflated tires not only wear out faster but also increase resistance to movement, which means that more fuel is burnt.

Inadequate behavior of the driver behind the wheel (improper choice of speeds, sharp acceleration and braking increase in the set speed), as well as self-adjustment (increasing the idle speed) and violation of the instructions for the operation of the car often leads to increased environmental pollution, reducing the effectiveness of efforts For the purposes of the design notes. Therefore, explanatory work of drivers' environment 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 machines (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 promote the development of cancer), such as benzapyrene.

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 engine of the Vehicle most of the time operates at idle, it is necessary to reduce the idle time with the engine running the vehicle when driving in a harsh state of the traffic flow.

A large number of harmful substances enters the atmosphere at:

1) delays of the vehicle ahead of traffic lights;

2) parking with engine running while waiting for an enabling signal;

3) starting from the place and dispersing.

In order to reduce emissions of harmful substances, it is necessary that the transport stream 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 the road network. Since the main streets are the busiest sections of the Street-road network, it is on them that up to 75% of all vehicles moving within the city are concentrated. Consequently, the territories along the main streets require special attention to improve the ecological situation.

The arrangement in cities of highways with an increased speed regime provides for increasing the capacity of the road Network, reducing the number of road accidents, isolating residential areas and making centers of attraction away from the presence of a high-intensity transport stream, and, consequently, improving the ecological situation. However, the highway for high-speed traffic is an expensive construction. Its construction justifies itself only in areas where the traffic flow is constantly present, having long-distance trips on the territory of the city. As a result, the main lines are intended only for the largest agglomerations.

Thus, in order to improve the environmental situation in the cities, it is necessary to minimize the accumulation of vehicles on the hauls and intersections with the help of various organizational and planning activities.

It is impossible to completely exclude the negative impact of transport on Nature, but it is possible and necessary to reduce the negative impact.

The main directions of environmental protection in transport are as follows:

1. Strict adherence to the rules of transportation of people and goods, which will make transport work more optimal, economically profitable, will reduce the costs of energy, fuel and other resources.

2. Conducting reconstruction of engines, which will reduce fuel consumption per unit of mileage, reduce noise and vibration (due to fundamentally new technological solutions), significantly reduce the content of harmful impurities in exhaust or off-gas.

3. Development of new types of engines (such as electric vehicles), which minimally pollute the environment, and introduce them into practice.

4. Development of new fuels that would be more environmentally friendly, i.e., when they burned, fewer substances with negative effects on human health and natural ecological processes would form.

5. Given that the amount of harmful contaminants depends on the engine operating mode, optimize the mode of traffic on the roads, as far as possible, excluding the occurrence of "traffic jams" and other difficulties when driving vehicles.

6. The use of new technologies of fuel combustion without the use of tetraethyl lead, which contribute to a more complete combustion of fuel.

7. Development of devices that capture or neutralize harmful contaminants contained in exhaust gases and equip them with vehicles.

8. Development of an optimum mode of operation of engines of different types and use of a computer for fine control of the combustion of fuel.

1.3.2 The influence of congestion on human psychology

The lower layers of the atmosphere are polluted with dust, which consists of asphalt concrete, spent rubber, abrasive, lead and other substances, some of which are carcinogenic and mutagenic. This negatively affects other road users - pedestrians. The highest concentration of harmful substances is concentrated in the air layer below 1 m from the surface.

Negative consequences affect not only humans, but also animals. The noise effect from highways is a negative factor, which leads to a decrease in the quality of environmental indicators in urban conditions. The noise pressure on highways that are capable of passing more than two thousand cars per hour is more than 80 dB. To reduce the level of this indicator set noise protection fences and plant green plantations along the highways.

Based on the information of the journal Psychological Science, "traffic jams" on the roads have a negative impact on the human psyche. This can significantly affect health and lead to serious diseases, which, no doubt, will not manifest themselves immediately. This statement came from researchers at the University of California.

In the 90-ies of the twentieth century, scientists conducted surveys. The respondents were 800 participants aged 25 to 74 years. All participants in the survey answered the questions asked, which were related to the state of health: anxiety, anxiety, lack of energy, and how often such conditions occurred. In the 2000s, scientists conducted another similar survey.

After this event, it became clear that human health depends more on small shocks (minor accidents or traffic jams) than from serious stressful situations. Scientists have proved that negative reactions to what happens around, accumulate and can lead to a serious mental disorder.

It is clear that congestion in the largest cities is long and long, so drivers in Kazakhstan show aggression towards each other [12]. Researchers argue that frequent stays in traffic jams can cause serious harm to health. A study by Australian scientists showed that about an hour after a person got into a traffic jam, the risk of myocardial infarction increases. Most likely, it was exhaust gases, noise and stress that became the main cause of a sudden increase in the number of heart attacks.

Long stay in the mash causes muscle tension, which significantly affects the fatigue of the driver.

Due to poor health of the driver and a malfunction of the vehicle, a negative situation may arise which will affect other road users and traffic safety. Therefore, it is necessary to regularly monitor the serviceability of the car, so as not to cause stress [13].

E.M Lobanov [14] generalized the influence of psychophysiological qualities of a person on safety. The change in the psychophysiological qualities of the driver's organism depends and comes from the influence of the traffic situation. They are invited to influence the formation of road conditions, based on these human capabilities.

Thus, it can be argued that psychophysiological characteristics are indicators of road conditions and causes of road accidents, which leads to congestion.

The psychological reaction of a person and the assessment of the situation that he makes are not always accurate. The eye, the person's ear react absolutely differently depending on age and skills. According to G. Knoflacher [15], a person can not correctly assess the characteristics of the traffic flow.

Traffic jams are the main cause of aggressive driver behavior. The lack of accurate information about the duration and cause of congestion, as well as the lack of a general picture of the traffic situation before the eyes can lead to a stressful situation.

In our time, this problem is important, as people are becoming less stress-resistant and more nervous. An extremely annoyed person at the wheel of a car can become dangerous to others. Negative emotional state should not affect the driving style.

1.4 Situation in Almaty

The southern capital of the Republic of Kazakhstan is unique in its physico-geographical and natural climatic characteristics. Almaty is located in the north of the mountain spurs of the mountain system of Tien Shan, at the northern foot of the Zailiysky Alatau, on the cones of the interfluve Ul'ken (Big) - Almaty and Kishi (Malaya) of Almaty. In Almaty, as it were, the natural zones of the severe north and hot south are crossed.

The complex terrain, climatic features create unfavorable conditions for the dispersion of impurities from low emission sources, as a result of which harmful substances accumulate in high concentrations, which then take part in the formation of smog phenomena.

Pollution of the atmospheric air of the city is one of the major factors of water and soil pollution, because due to the absence of storm sewage, flushing of pollutants into water bodies with thawed and storm water occurs.

The most polluted environment in Almaty, according to the Center for Environmental Monitoring, is the city's atmospheric air.

The main source of atmospheric air pollution in Almaty is motor transport. As a result, in the atmospheric air of Almaty, there is an increased content of formaldehyde, nitrogen dioxide, phenols, carbon monoxide.

The mortality rate (per 1,000 population) increased from 8.6 to 11 with an average republican figure of 10.1, and as a consequence, the natural increase (decrease) per 1000 people from 7.2 to the minus value (-).

On the territory of Almaty at the moment there are only 6 posts that monitor atmospheric air instead of 10-20 points, which are necessary for cities in accordance with regulatory requirements. Being one of the most beautiful cities of our country, Almaty remains one of the most dysfunctional in the ecological plan.

Pollution of the atmosphere of our metropolis by automobile emissions lies in one of the main troubles of Almaty. Due to the fact that they are too narrow, and even with a lot of crossroads and traffic lights, cars often have to stop, spend hours in traffic jams. At each traffic light and in places of congestion, the amount of automobile emissions goes off scale, since under idling and speed dialing conditions, maximum volumes of exhaust gases are released into the atmosphere.

As a rule, the central, the most densely populated areas of megacities are exposed to the greatest pollution by motor transport. As a result, from the pollution of the atmosphere, hundreds of thousands of residents of every major city of Kazakhstan suffer from automobile emissions. The greatest danger is the exhaust gases for small children, since the height of automobile emissions does not reach 1 m.

Causes of congestion

Congestion occurs because of low road capacity; Disorderly parking of vehicles on the carriageway; Set of traffic lights and time wasting while waiting for their switching; Lack of pedestrian lanes and erratic pedestrian crossings; Unpopularity of public transport; Culture of drivers, lack of mutual respect; Disorderly movement of special equipment and heavy vehicles; 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 motorists 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);

Absence of parking spaces, violation of parking rules;

Roadworks;

Traffic jams during the working day

During most of the year, peak hours are kept in Almaty: in the morning from 8:00 to 10:00 and in the evening from 17:00 to 19:00, and in the evening the load is one and a half to two points higher than in the morning. In July and August, the morning rush almost disappears. In September, the situation worsens, first of all, in the morning and in the evening, and in the afternoon the streets are loaded, as in the summer.

Experts carefully study all restrictive measures before making any decisions. It was proved that the left turns increase congestion and congestion, in connection with which it was decided to limit several left turns, which will be established along Abai Avenue.

For example, there are very few intersections in Almaty, where there is a separate section for turning left. As a result, cars are hammered in a number of ways and significantly reduce the throughput of the intersection, "he said." To solve these problems, it is enough to prohibit the left turn at the intersection and let the whole flow of cars to the right, so that after driving to the gap in the dividing strip, wherever they turn left The most you can speed up the flow of machines and not take up a whole strip.

On the road with heavy traffic, there may be many who want to turn around, and the length of the section in the break of the dividing strip, at times, can freely accommodate up to 2-3 cars, thereby further speeding up the flow of cars.

In Almaty, on the roads, as a rule, half of the first row is occupied by cars parked in an unauthorized place, and the left row, though freer, as it approaches the intersection, ceases to move. 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.

As a result, a lot of emergency situations are created when the car from the second row approaches the intersection abruptly starts to be rearranged to the first row, or, for example, when the car clamped to the right of parked cars occupies half of the second row.

It is necessary to liberate all key streets from the parking lot everywhere to ensure that they pass through and unhindered traffic.

But in addition to this, the city authorities should seriously think about introducing an additional band to turn left.

Some will argue that the width of the road for this venture is not enough, but you should take into account the fact that the standard bandwidth we have 3.75 meters, when in other countries are quite cost and smaller strips (3.5 in Europe, 3.25 in Great Britain, 3.2 in Japan).

Conclusions on the first chapter

1. Existing concepts and basic parameters of traffic congestion include the formation of queues, the loss of travel time, the reduction in speed and throughput and the increase in traffic density.

2. Geometric parameters The road network, urban planning, organization of the parking space have a direct impact on the occurrence of congestion and require constant monitoring and development under the influence of the forecasted situation.

3. The consequences arising from road congestion are presented and analyzed. The influence of congestion on the ecological situation of cities, as well as the negative impact on the psychophysiological state and health of people is examined.

4. The analysis of existing models and methods of "fighting" with the phenomena of congestion is carried out. It is proposed to use the modeling of

transport flows, which facilitates the solution of transport problems by an analytical method.

2 ANALYSIS OF EXISTING METHODS OF ESTIMATION OF DELAYS OF TRANSPORT FLOW ON THE STREET-ROAD NETWORK

2.1 Analysis of existing methods for calculating and estimating traffic flow delays

The length of delay in motor vehicles has become widely accepted as one of the criteria for optimizing traffic management, both at a single intersection and on the road network as a whole [11].

To date, there are two main approaches to determining the delay of vehicles. The first approach is based on a macroscopic model of the transport stream description and defines the transport delay as a loss of time for forced stopping of vehicles before crossing, railway crossings, during congestion on sections of the road network, and also because of the slowing down of the traffic flow relative to the average Speed of free traffic on a specific section of the road network.

The second approach determines the delay, as the average waiting time of the vehicle in the queue. The length of the queue is the total number of vehicles waiting for service before crossing.

At the present time, models that combine both the deterministic and stochastic components of delay are widely used. The deterministic component is determined in accordance with the following provisions:

- at the beginning of the enabling signal, the turn of vehicles is zero;
- ATS arrive in the same groups with a traffic intensity q per cycle;
- the crossing is made by the same groups with the intensity, which is equal to the saturation flux S in the presence of a queue, and with an intensity that is equal to the intensity of arrival at its departure;
- The demand of vehicles does not exceed the capacity of the intersection element, which is defined as the ratio of the saturation flux S to the ratio of the resolution signal to the cycle time (g / c).

At the moment, there are different models of delays for stationary traffic conditions with approximation elements and so-called "accurate" models.

For the first time, the model of estimating the delay in rigid traffic regulation was proposed by Beckman with the assumption of a binominal arrival process of vehicles and the deterministic nature of the service process :

$$d = \frac{c-g}{c(1-q/s)}\left[\frac{Q_0}{q} + \frac{c-g+1}{2}\right] \qquad (1.3)$$

Where: c - length of the control cycle, s;
g – effective duration of the green signal, s;
q – the arrival rate of the vehicle, aut./s;
S – the intensity of the departure from the queue, aut./s;
Q_0 - value of the remaining queue, aut.

The first widely used approximate formula was obtained by Webster with a combination of the theoretical approach and numerical modeling:

$$d=\frac{c(1-g/c)^2}{2(1-(g/c)x)}+\frac{x^2}{2q(1-x)}-0,65(\frac{c}{q^2})^{\frac{1}{3}}x^{2+5(g/c)} \quad (1.4)$$

Where d is the average delay of one Transport facility per cycle, s;
c - length of the control cycle, s;
g - effective duration of the green signal, s;
x - is the degree of saturation of the direction of motion;
q - the arrival rate of the vehicle, aut./s.

The first component of equation (1.15) represents a delay, provided the arrival of the traffic flow is stationary, and the second component determines the random component of the process. The latter is known as the "random delay", under the assumption of a Poisson arrival process and a constant traffic intensity of vehicles that corresponds to the throughput. The third component corrects the modeled delay value and, usually, makes up 10 percent of the first two components of the equation (1.15), which will allow us to simplify the formula further by taking the third component as the coefficient equal to 0.9.

Further approximation of the equation was aimed at simplification by reducing the third and fourth terms of the equation, which, as a rule, are much less order than the first two. This approach was used by Miller in deriving the approximating formula:

$$d=\frac{(1-g/c)}{2(1-(g/s)}\left[c(1-g/c)+\frac{2Q_0}{q}\right]; \quad (1.5)$$

Miller also received the expression for a saturated queue with Poisson arrival and service time equal to the duration of the resolving signal [41,42]:

$$Q_0=\frac{\exp\left[-1.33\sqrt{Sg}(1-x)/x\right]}{2(1-x)}; \quad (1.6)$$

Newell created its own model for delaying the transport flow, which made it possible to improve the accuracy of determining the delay at an average load [30,31]:

$$d=\frac{c\cdot(1-g/c)^2}{2\cdot(1-q/s)}+\frac{Q_0}{q}+\frac{(1-g/c)\cdot I}{2\cdot S\cdot(1-q/S)^2} \quad (1.7)$$

Further attempts to improve the accuracy of the models did not lead to significant results.

The delay models above require stochastic equilibrium. To achieve it, an infinite time is required under constant traffic conditions (arrival, maintenance, regulation). With a low ratio of traffic intensity to road capacity, this is achieved within reasonable time limits, therefore such models are an acceptable approximation of real processes. When the intensity of the movement is equal to the value of the capacity, the time that is necessary to achieve such an equilibrium, as a rule, exceeds the interval within which the demand is stable. In addition, in many cases the magnitude of the traffic intensity exceeds the capacity in this case, the limitations of models are violated.

Analyzing the methods for determining transport delays, it can be concluded that they are aimed only at quantifying them (in seconds for one car). None of the methods makes it possible to calculate the probability of a traffic congestion (such a transport delay within which the traffic flow can be classified as a traffic jam) at the intersections on the basis of which it would be possible to plan the transportation route in the city

2.2 Investigation of the appearance of a traffic jam at an intersection

Domestic and foreign scientists-researchers G.I. Klinkovshtein, V.I. Konoplyanko, V.A. Korchagin, Y.A. Kremenets, E. M. Lobanov, V.V. Silyanov, M.R. Yakimov, P. Przhybil, F.V. Webster in the field of road traffic use a variety of methods. Some of these can be accessed by only one person without specialized equipment, others are at a higher level and are very complex, using road laboratories and modern technologies. A large number of different methods suggest that, firstly, there is a wide range of tasks that can be solved through organizational approaches, and secondly, constantly evolving technologies, improvement of hardware to collect and process the necessary information [4].

The task of the pilot study was to check the validity of the estimation of traffic jams that occur on the carriageway. In the studies of traffic jams, the following were included: measurements of traffic flows, in particular, the number of vehicles that stopped before the stop line at the red traffic light signal (ie, vehicles that did not have time to pass through the intersection to the green traffic signal), as well as vehicles that were added To the traffic light already standing on the red; Modes of traffic signal regulation, geometric parameters, condition of the road surface. The centers of traffic jams in peak hours, the periods of increase and decrease in the number of vehicles on the days of the week, months and periods of the year were determined.

In order to investigate the congestion in Almaty, during the year, problematic intersections with traffic light regulation were examined. Geometric parameters and parameters of the transport flow of these sections were studied: the number of bands, the intersection scheme, weather and climate conditions, the state of the carriageway, the level of loading. The road network, the "origin" of the harsh phenomena. The data is collected by video recording on a smartphone and produced. For all the intersections under investigation, congestion is typical during peak hours.

In all cases, the maximum congestion was observed street traffic at peak time, i.e. morning and evening hours. Three intersections of Bostandyks and Almalinsky districts of Almaty have been investigated. During the year, the data were recorded during peak hours by the number of vehicles standing at the intersection to the inhibitory signal and by the number of vehicles added to the vehicle standing on the prohibiting traffic signal. As a result of the survey, the dependence of the number of vehicles accumulating on the inhibiting signal from the time interval was revealed.

For each investigated intersection, graphs were constructed that depict the nature of the origin of the phenomena of the storm, namely, the initial stage of the formation of congestion, congestion, the stage of the departure of vehicles from the intersection. The considered intersections are presented in Table 2.

On the basis of experimental data, smoothed values are calculated, in order to minimize the appearance of points of random deviation from the curve of the calculated value of the trend process; Calculated predicted values for different periods of time;

Table 2

Investigated objects

№	Name of the investigated intersection
1	Tole bi street - Auezov street
2	Timiryazev street - Zharokov street
3	Zhandosova Street - Auezov Street

In this paper, using the example of one of the considered X-shaped intersections during the peak hour, having two main lines along the main road in the forward and backward directions, the following initial data were determined for the secondary one-one strip in the forward and backward directions: cycle duration, Component Tc = 60s, the intermediate cycle Tpr = 4s, the green cycle time is Tgr = 35s, prohibiting - Tr = 21s. The number of vehicles approaching the intersection with a red traffic light signal, as well as the number of vehicles added to the vehicle, which is already in front of the stop line, was determined every minute and every five minutes during the whole hour. From the experimental data, one can see how the "congestion" of the congestion occurs, the congestion and loss of the vehicle directly in the area under consideration is the Street-road network.

Table 3 presents the experimental data: 1) the number of vehicles that accumulated on the prohibition signal of the traffic light on the line before the intersection; 2) TS, which were added to the already existing vehicles on the basis of data collected using video recording on the site in question. The street network of Almaty city (Zhandosova street).

Statistics are collected from Monday to Friday in the morning rush hour. The number of TCX is the number of transport vehicles approaching the intersection to the prohibition signal of the traffic light, the number of TCY- the number of transport added to the transport facilities that are already in front of the stop line.

Statistical data on the number of transoptent funds are presented in time intervals (which were currently 5 minutes) and on the days of the week (Monday-Friday) (Table 3). In view of this, it seems reasonable to use the theory of random processes for the analysis and prediction of ground states.

Table 3

Statistics on the accumulation of cars at the crossroads

Time, Min	Day of the week								
	Monday			Wednesday			Friday		
	Qty. TC, X	Qty. TC, Y	Всего	Qty. TC, X	Qty. TC, Y	Всего	Qty. TC, X	Qty. TC, Y	Всего
5	23	15	38	2	31	33	4	31	35
10	29	22	51	4	52	56	5	52	57
15	37	26	63	21	50	71	23	50	73
20	46	39	85	23	44	67	30	44	74
25	70	55	125	50	56	106	55	56	111
30	91	79	170	86	67	153	107	67	174
35	119	98	217	196	34	230	183	53	236
40	154	112	266	237	22	259	243	21	264
45	192	101	293	238	16	254	229	17	246
50	200	87	287	92	46	138	101	51	152
55	198	61	259	15	61	79	21	71	92

Continue table 3

60	187	34	221	4	20	24	4	26	30
Σ	1346	707	2053	968	499	1467	1005	539	1544

According to the results of the surveys, it can be seen from the statistics that The harsh state has a cyclic character, which consists of Three parts, namely:

1) the initial stage of congestion (when the intensity of vehicles increases and the vehicles facing a stop line do not have time to pass on a permissive signal of a traffic light, thereby creating a turn on a stretch, also the speed of vehicles drops and begins to tend to zero);

2) congestion (when the intensity tends to be equal to the throughput ability or exceeds it, as well as the speed of vehicles tend to zero);

3) the stage of departure of vehicles (when the intensity is reduced and the vehicles standing on the prohibiting signal of the traffic light manage to pass the intersection to the resolving signal without leaving a queue, also the speed of the vehicle is increased).

It is worth noting that the weekend saw the smallest number of cars and the street road network coped.

2.3 Analysis of methods to prevent traffic jams

As a rule, congestion occurs most often, as well as they are prolonged and block traffic on the roadway due to inefficient operation of the road network. In order to prevent these phenomena, a set of measures is needed. As a result of research and practical experience in this area, comprehensive measures have been developed to improve the current situation on the street-road network. Part of these activities is aimed at the specific identification and prevention of the state of fire. Such technology is developed and works in Helsinki. The essence of such a project is the use of controlled speed limit signs and information boards that notify traffic participants about the available congestion. Such systems are used in other cities, but the effect of them largely depends on the driver's staff.

The general principles of traffic flow management can be presented in the following form figure 12:

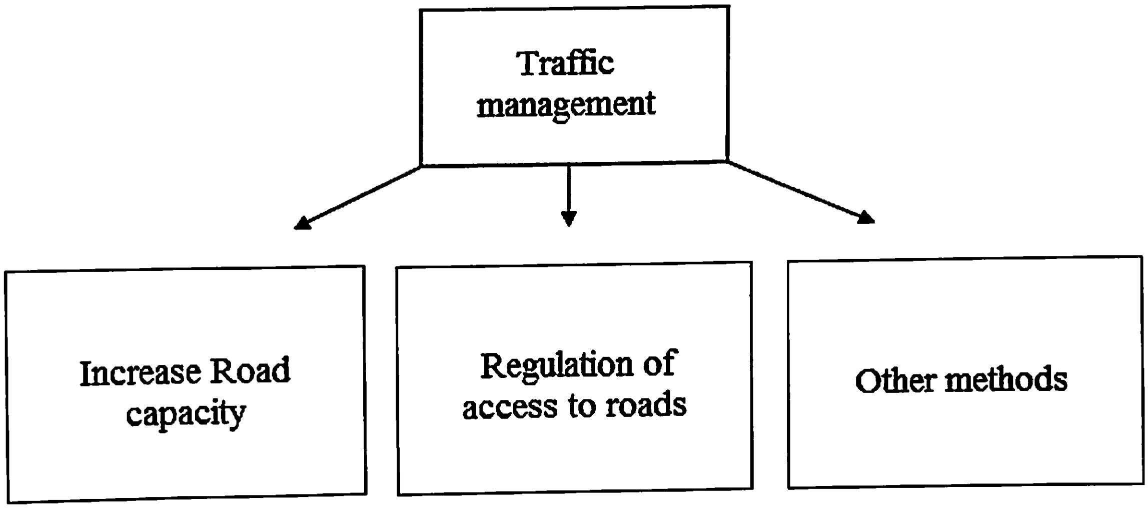

Figure 12. General principles of traffic flow management.

In Kazakhstan, the most common method to combat traffic congestion is the optimization of traffic light. This method is effective only if comprehensive regulation is implemented on a city or district scale. However, if the trunk is very heavily overloaded, even this method will be ineffective.

The following methods have been widely used in the world [9,10]:

Some of the measures of the complex are:

– Road construction; Construction of bypass roads, multi-level interchanges, overground and underground passages, extra-parking lots and parking lots. As a result of these activities, the throughput of the city road network increases, and the delays of the TS associated with the transitional movement are reduced. For example, regional and road construction projects.

– Decrease in traffic intensity, i.e. Paid parking, a complete ban on parking, increasing the attractiveness of route and passenger transport, automatic control systems for entry into courtyard areas. As a result, the speed of communication increases, transport delays are reduced, and the shorelines in the city are reduced. For example, in the city of Belgorod, a transition to a system of paid parking lots, the prohibition of parking in heavily loaded streets [17].

– Optimization of the use of the existing road network, i.e. Organization of unilateral and reverse movement, selection of optimal schemes and algorithms for traffic signal control objects, change of the intersection plan, development and implementation of automated road traffic control systems and ITS (intelligent transportation system). As a result of these measures, the capacity of the Street-road network will increase by 20-30%; When implementing the ACSD and ITS: reducing the delays of vehicles and passengers en route by 20-40%, reducing environmental pollution, noise level, gas levels by 20-30% [17].

Researchers note that, if there is a deficit in the width of the carriageway, congestion can not be eliminated with the help of organizational and managerial measures, and only the places of their localization are transferred, thus the severity of this problem is temporarily alleviated. Only with a high level of transport infrastructure development is it possible to improve this transport problem of cities.

Paid entry to the city center is characterized by the presence of a fixed tariff for the right of access to the restricted area. The cost of payment is made once a day, regardless of how many times the driver crosses the border of the zone. The form of payment is diverse, including sms messages.

The most famous method was in London. The number of cars entering the designated area, as planned, declined, while the number of passengers entering public urban passenger transport increased.

In large cities, a network of bypass roads is envisaged to solve transport problems. They perform the basic transport work that connects the city with a suburban network, and also provides the bulk of traffic across the city.

Organizational measures to prevent congestion are carried out in almost all countries of the world. Paid parking in the city center is common, as well as the arrangement of a parking space near public transport stops[18].

In European countries, automated parking systems are used. The installed radio tag in the car, allows you to transmit information about the location of the vehicle to radio stations. Payment for parking is charged from the personal account of the owner of the car. Vehicles with missing radiometrics are accounted for by the specialized services of the parking space using the method of recognition of registration marks.

The following activities are used to prevent traffic congestion in major cities:

- The use of a certain-road travel system at rush hour;
- The storage of paid parking lots in the central part of the city;
- -Establishment of urban passenger transport routes: construction of new subway stations, extension of the length of land transport routes;
- -An automated traffic control system with adaptive regulation of traffic lights;
- Prohibition of the entry of a large transport;
- Information boards reporting incidents and congestions;
- Multi-level interchanges, highways, allowing to unload the road network;
- - navigation devices, through which information about the situation on the road network is reflected through the satellite;
- construction of bypass roads;
- separate lanes marked with markings or low curbs for the movement of passenger vehicles and buses that carry more than one person are allocated, and also allow traffic congestion during peak hours [19, 20, 21].

The introduction of an intelligent transport system (ITS) based on modern information technology is an effective way to increase the capacity of urban roads.

In this case, information technologies are used to simulate transport processes in order to determine the optimal location of the centers of attraction, which will ensure maximum throughput, both in individual sections and the road network as a whole, in conditions of growth of the urban vehicle fleet [22].

Repeatedly proved the effectiveness of the application of simulation of traffic flows. In the process of modeling with the use of modern computer technology, a great economic effect is achieved with minimal effort and minimal time for conducting the research.

In scientific practice, analog modeling is widely used to study various processes, based on the analogy of physical phenomena of different nature, but described by the same mathematical (differential, algebraic or some other) equations.

One of the types of analog simulation is simulation based on electrohydrodynamic analogy, with the model choosing the electrical system in most cases, in view of the convenience of measuring currents and electrical potentials.

In the works of the scientific school of the department "Organization and traffic safety" of the BSTU named after VG. Shukhov under the guidance of Professor Shutov A.I. On the basis of the basic laws of electric current, questions were considered on the development of a methodology for studying the parameters of the transport flow.

The developed principle of modeling traffic flows, based on electrohydrodynamic analogy, solves numerous tasks to ensure the safe and efficient movement of vehicles, but this principle is not applicable in dynamics.

There are several states of the transport flow, one of which is the traffic congestion, which is of greatest interest for research [23].

One of the large groups of models of the transport flow can be attributed models, the transport flow in which becomes similar to the flow of fluid, the so-called hydrodynamic models [23].

Here, the transport flow is understood as the flow of a one-dimensional compressible fluid. There are assumptions for the conservation of flow [5]:

$$\rho + \left[V_{\max} \rho \left(1 - \frac{\rho}{\rho} \right) \right]_x = 0, x \in R, t > 0 \tag{1.7}$$

Where ρ (x, t) is the density of the transport flow at the point x at time t> 0 (the number of vehicles at a certain distance), ρ max - the density of the traffic flow in the plug;

V (x, t) is the vehicle speed at point x at time t;

Vmax - the maximum speed of the vehicle, when the road network is free.

There is a linear relationship between the density of the transport flow and its speed [5,24,25]:

$$V(\rho) = V_{\max} \left(1 - \frac{\rho}{\rho_{\max}} \right), 0 \le \rho \le \rho_{\max} \tag{1.8}$$

In the motion, the transport flow, by analogy with the fluid phase transitions [26], determines the phase states of the flow [27]:

– free flow (drivers choose speed based on free traffic);

– Synchronized flow (drivers determine the speed according to the speed of the traffic flow);

– Wide moving "jams" (groups of vehicles move in the same way as pieces of ice in a stream of water);

– Start-stop motion (traffic flow resembles the flow of freezing water). Start-stop motion and congestion are formed in a dense flow, when the distance between vehicles is less than the critical value [28, 29].

Also, the model of kinematic waves describes the "bounce" movement of vehicles. Some assumptions have been made in the construction [30]: the transport flow is continuous; The intensity of the traffic flow is defined as the number of vehicles crossing the border for a certain period of time; Average speed - is a function of density; The number of vehicles is saved on the site in the absence of a branch of the Road Network.

Hydrodynamic models of transport flows inherent in the emergence of an unstable state, stationarity. Moreover, they do not allow describing the process of flow return from an unstable state to a stable one at a low level of density [31].

The second-order hydrodynamic models [32, 33, 34, 35] took into account all these limitations.

In probabilistic (stochastic) theories, the transport stream is viewed as the interaction of vehicles on the Road Network. These models allow modeling of transport processes at intersections, including a harsh state at the intersection.

The stochastic model [5] considers the accumulation of vehicles in front of adjustable intersections. The four variants proposed in [5] allow us to say that in the model the results of the average queue length have a significant dependence on the probability of a complete queuing of the queue. Model [5] is not applicable at the multi-way intersection.

To date, there are a number of techniques [4, 5], which allow to optimize the movement of vehicles in various areas of the road network. The use of these techniques can reduce the number of critical situations and increase the capacity of the road network.

For effective application of the above methods it is advisable to use modern information technologies and software. This helps to significantly increase the efficiency of work and organize electronic storage of input and output data, optimize the processes of their input, editing, analysis and visual presentation, quickly and timely correct the data and get relevant results.

To increase the reliability it is advisable to consider not a single moving car, but a transport stream as a whole. Traffic flows are made up of movements made by traffic participants. The main characteristics that determine the number of movements and their distribution on the city's transport network are the flow-forming factors of the transport network.

A characteristic feature of the movement is the uneven distribution of traffic flows over time. Within a day, periods of maximum movement concentration are formed, so-called peak hours. To effectively solve the problem of congestion, it is required to numerically express the characteristics of the transport stream.

To do this, it is necessary to create a computerized model, the main task of which will be the regulation of traffic flows at the intersection. One of the main tasks is to determine the length of the queue (the size of the traffic jam at the intersection), as well as the capacity [84].

In order to understand the cause of the situation with traffic jams, it is necessary to study in detail the process of traffic flow as a transport model [8]. In [35], the dependence of the queue length on the stop time of the vehicle at the traffic light object is considered.

Using the obtained dependence, the parameters of the formation of the congestion (time or queue length) at the intersection with traffic light regulation are determined.

Today, the software of expert systems is widely used, which specialize in a narrowly focused field. Widely used such systems as RoadExpert, «ТЕНДЕР», Intelligence Transport Systems.

Typically, RoadExpert, «ТЕНДЕР», Intelligence Transport Systems for the modeling of the transport flow apply graph theory, since traffic flow forecasting is an important indicator of the transport process [36].

Research of Pechersky M.P. And Horovich BG. Talk about the phenomena of the arc in such a way that at first a so-called initial congestion occurs, caused by the formation of long lines at a regulated intersection.

The next stage with the growth of queues is a secondary congestion, which appears in connection with the blocking of an adjacent intersection by the initial congestion.

As a result of secondary congestion, there are comprehensive congestion that cover significant areas of the street-road network.

Factors contributing to the emergence of a comprehensive congestion:

- drivers of cars moving along main roads are reluctant to "accept" alternative secondary roads;
- because of poor-quality management, the attempt to eliminate the congestion in one direction of traffic can increase the degree of saturation of other directions;
- unregulated intersections do not fall under the sphere of influence of the traffic control system.

To address emerging issues, a principled approach to the solution of the problem is needed. The solution of the problem is transferred to the dispatch control contour, which in case of harsh situations includes: determining the place and time of the mash; traffic control in the area covered by a traffic jam with the help of a special algorithm and a set of special technical means; determination of the moment of the end of the congestion [37].

To prevent congestion on the road, city authorities should pay attention to the redevelopment of intersections and the expansion of the roadway. In order to prevent the emergence of harsh situations, it is necessary to build multi-level interchanges, and it is necessary to allocate a separate lane for traffic of urban transport and taxis.

The most classic way to "fight" with congestion is to increase the capacity of the City Road Network.

In order to reduce road congestion to a minimum value, many countries of the world have their own methods. Firstly, at the place where the congestion occurs, a restriction is imposed on driving with a private car, this means that drivers are obliged to leave their vehicle in the parking lot and change over to the city transport; Secondly, the restriction in the center of the city parking lots; Thirdly, in some cities the movement of Freight transport to the central part is prohibited [16].

Analyzing the considered methods of "fighting" with congestion, we can conclude that each of them has its advantages and disadvantages.

2.3.1 Transfer of a pedestrian crossing to increase the capacity

Consider how, with minimum costs, increase the capacity of most streets in Almaty, which have long established themselves as one of the busiest (see Figure 13). For example:

We move along the vertical street upwards, we approach the intersection with the horizontal street. Since there are 2 lanes on this section for movement in one direction, we take a place in the far right row (the left turn is made from the extreme left). The traffic light signaling the traffic lights up, and the whole right-hand row stands and stands. And all because the driver of the first car, making a right turn, starts to pass pedestrians crossing the horizontal street from point A to point B, and the second car turning to the right paralyzes traffic that moves straight.

Pedestrian traffic in the central regions of Almaty, I must say, is quite large.

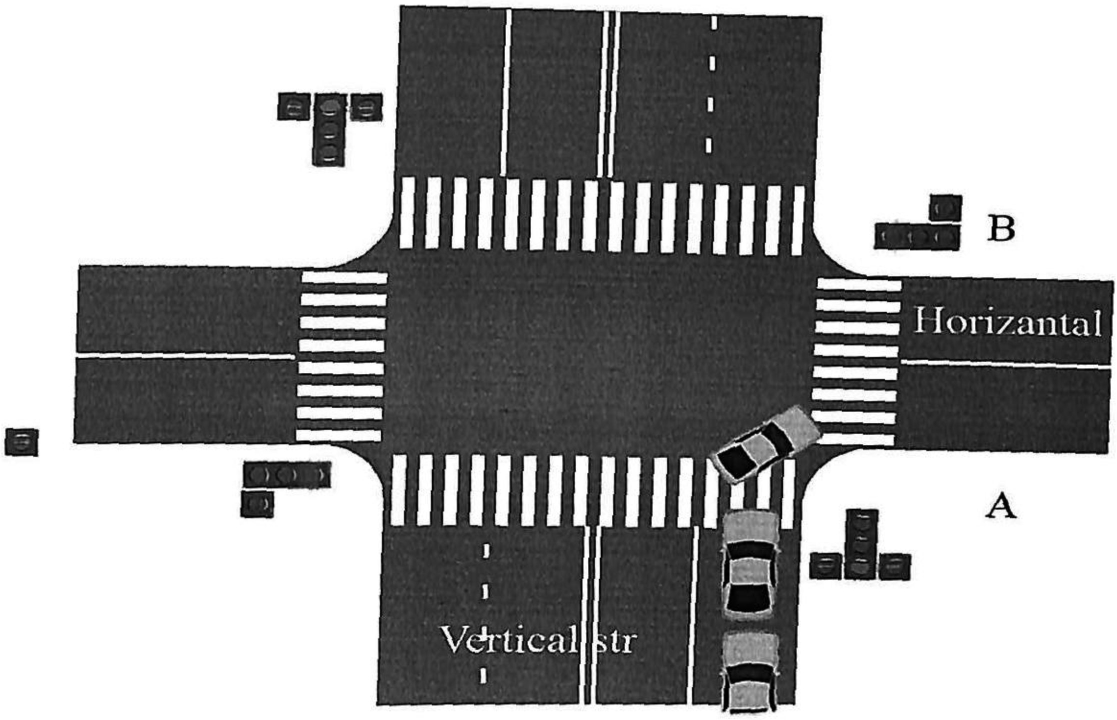

Figure 13

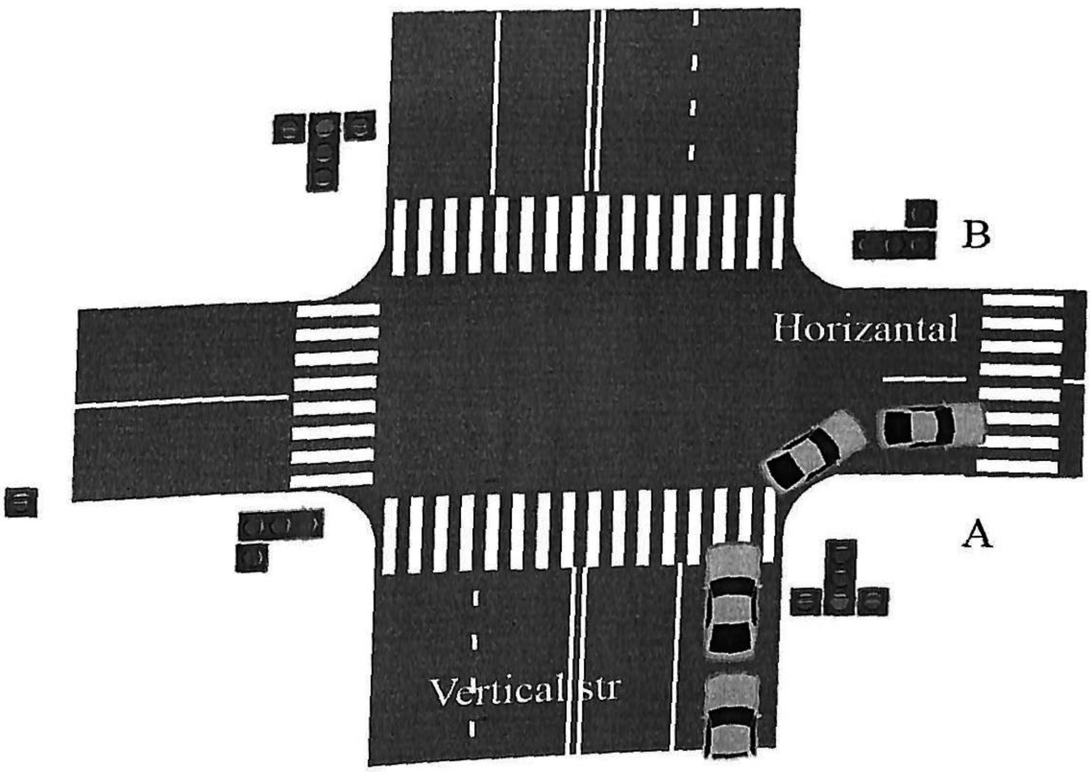

Figure 14

Ideally, of course, you need to expand the roadway and attach a third strip, but because of the lack of space, you can implement a more "budget" option. Namely - to move the pedestrian crossing from the edge of the intersection with the vertical street to 10 meters instead of the existing 6.5 meters.

Increasing the distance by only 3.5 meters will make room for another right-turning vehicle or for a small bus (see Figure 14).

Transport, which needs to move directly, will be able to continue its movement without difficulties, thereby significantly increasing the throughput of this transport hub.

The work on the transfer of pedestrian crossings requires minimal financial and time costs, and the throughput of intersections due to a reduction in the number of congestion will grow at times.

According to preliminary calculations, the throughput of intersections will grow by about 1500-2000 cars daily.

3 MODELING THE PROCESS OCCURRENCE OF A PILEUP AND CALCULATIONS OF THROUGHPUT OF HIGHWAYS

3.1 Determination of throughput highways and level of congestion

Throughput of the carriageway is determined by the number of lanes and the capacity of each of them, the nature of traffic on the highway (continuous or adjustable).

Calculation of throughput with a mixed flow in the structure is done in the units given.

The theoretical bandwidth of one lane (N_T) is determined by the formula:

$$N = \frac{V3600}{L} \tag{1.9}$$

Where V is the speed of flow, m/s, taken depending on the class of highways according to the building norms and rules 2.07.01-89 * [2] and "Recommendations for the design of streets and roads of urban and rural settlements" depending on the category of highways " [4];

It should be taken into account that the actual flow rates are 15-20% lower than the design speeds of a single car;

L - the value of the dynamic overall dimensions, m.

Dynamic dimension - the minimum distance between the front bumpers of cars moving behind one another, ensuring traffic safety.

The calculation of Throughput is carried out from the condition of impossibility of transition to an adjacent strip with full use of the capacity of the carriageway. Under these conditions, the value of L is determined using the third group of simplified dynamic motion models using the formula:

$$L = t_p V + (l''_m - l'_m) + l_o + l_a \tag{2.0}$$

Where t_p – the reaction time of the driver from the beginning of deceleration of the front car to the beginning of deceleration of the rear car.

According to observations t_p = 0,60–0,83 s. Taking into account the response time of the braking system is adopted for calculation t_p = 1 s;

l_o – safety distance between stopped vehicles (assumed to be 2 m);

l_a – length of the car (accepted 5 m);

l'_m – braking distance of the front car, m;

l''_m – braking distance of the rear car m.

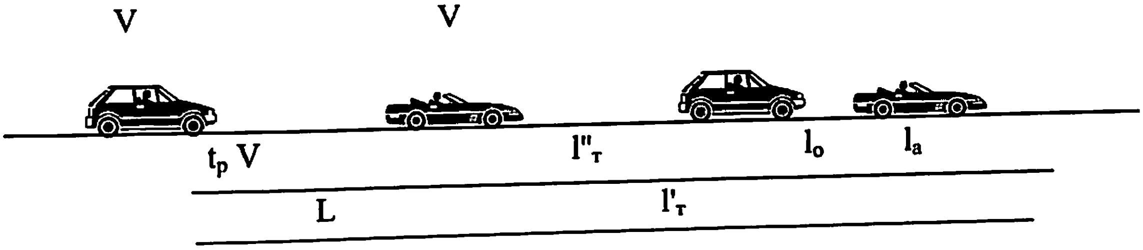

Figure 15. Capacity calculation scheme
Simplified formula for straight horizontal path sections

$$N = \frac{V3600}{V + 7 + 0{,}13V^2} \quad (2.1)$$

The capacity of the multi-lane carriageway (Nм) is determined taking into account the distribution of vehicles along the lanes:

a) mixed or same flow

$$N_M = N\gamma\alpha, \quad (2.2)$$

Where γ– is the multi-band coefficient, taken as a function of the number of lanes in one direction (n):

n= 1, γ= 1,0
n = 2, γ= 1,9
n= 3, γ= 2,7
n= 4, γ= 3,5;

α– is a coefficient that takes into account the reduction in throughput due to traffic light regulation.

The coefficient α is determined by the formula

$$\alpha = \frac{T_1}{T_2} = \frac{L_n}{L_n + \frac{V^2}{2}(\frac{1}{\alpha} + \frac{1}{b}) + \Delta tV} \quad (2.3)$$

Where T1 is the theoretical time for the vehicle to pass the distance between intersections at the design speed without delays, mines;

T2 - estimated time for the vehicle to travel the same distance, taking into account the delay before the intersection, the time for acceleration and braking, mines;

L_n – distance between intersections, m;

a –acceleration during acceleration (1,0 m/s^2);

b – brake deceleration (1,5 m/s^2);

t – the average delay of cars before traffic lights, which is determined by the formula:

$$\Delta t = \frac{T_{Ц} - t_g}{2} \quad (2.4)$$

Where T_c - duration of the control cycle, c; t_g - duration of the green phase, sec.

For example, with an average vehicle delay at a traffic light of t = 16,5 c (at T = 60 c, t_g = 27 c) the throughput is reduced by a 55% drop at 400 m / s at a flow rate of 60 km / h and by 49% at Speed of 50 km / h (Figure 16). For highways of continuous and continuous motion, the coefficient α = 1.

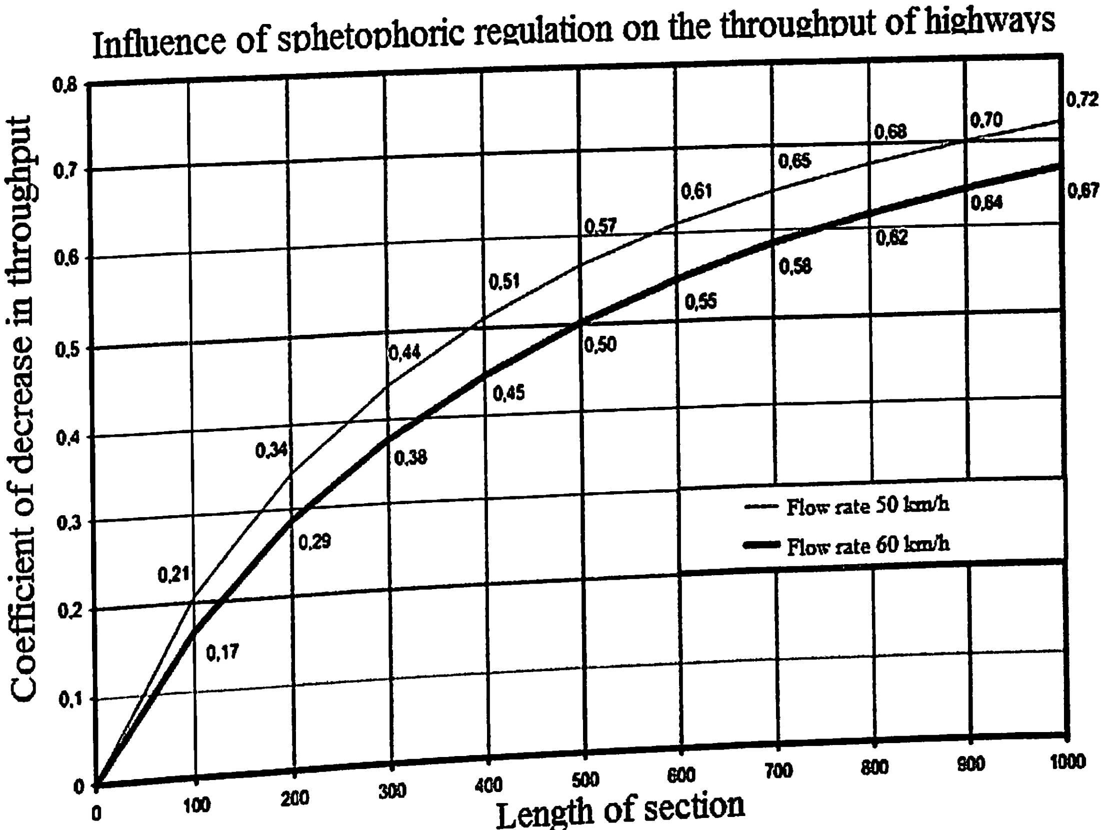

Figure 16. Effect of traffic light regulation on the throughput of highways

B) specialization of lanes by modes of transport

In this case, the capacity and load level are calculated separately for the lanes intended for each type of vehicle.

The throughput of the entire carriageway of the highway will be determined by summing the bandwidth of the bands allocated for each mode of transport (Σ Ni).

For preliminary calculations, the bandwidth of one lane of the carriageway of streets and roads is allowed to be accepted according to the recommendations of the « Guidelines for the design of city streets and roads» [3].

Table 4

Vehicles	The greatest number of homogeneous physical vehicles in 1h.		
	At crossings in different levels		When crossing in one level
	On highways	On the main streets of continuous traffic	
Cars	1200–1500	1000–1200	600–700
Trucks	600–800	500–650	300–400
Buses	200–300	150–250	100–150
Trolleybuses	–	110–130	70–90

The degree of use of the capacity of the street (road) is characterized by the ratio of the intensity of the flow (N_{exis}) to the capacity of the carriageway (N_M)

$$Z = \frac{N_{exis}}{N_M} \tag{2.5}$$

This ratio is called the traffic load level of the carriageway and is within the limits O <= Z <= 1.

At the loading level Z = 0,3-0,45 the most stable state of the flow is observed in the characteristics of the motion. The change in lanes is practically unlimited. The closer the value of Z to 1, the higher the traffic flow density, the lower the speed, the more difficult the traffic conditions [4].

Work in bandwidth mode is unprofitable in many ways. With a loading level Z> = 0.8, the saturation of the flow is extreme, the flow is unstable, congestion is constantly generated, the change in the bands is very difficult, the average speed is 10-12 km / h, transport costs are increasing. The exploitation of streets at this level of loading is not expedient.

When Z = 1, a traffic congestion is formed. Therefore, at the loading level Z> = 0.8, the capacity of the streets is almost exhausted.

3.2 Throughput of the street-road network

The planning decision of the transport nodes depends on the class of the mains forming the node, and on the size of the transport load that determines the way the traffic is organized. The calculation of capacity and loading levels is necessary for choosing the most rational traffic organization with the prevailing traffic flow intensity. The basis for calculating the throughput of unregulated and self-regulating nodes is the theory of the motion of transport flows, which studies the regularities of the distribution of intervals between moving cars.

The throughput of the regulated nodes is determined by the capacity of the trunk in the section of the stop line and is determined by the capacity of one band, the number of lanes, the organization of traffic in the node, and the regulating regime. Possible schemes of traffic organization for 2-, 3- and 4-stroke regulation are given and recommendations are given for calculating the capacity in each specific situation - for different widths of the carriageway, under different conditions of traffic organization and regulation.

The throughput of unregulated intersections in one level.

Since the intersecting traffic streets are divided into main and secondary, and the main right is provided with the right of way, cars of a secondary direction cross the main stream only if there are sufficiently large gaps in it.

In accordance with the observation data [8], the interval in the main stream t_m is considered sufficient to perform a maneuver by a secondary vehicle, provided that $t_m > t_{br}$.

Where t_{br} – is the boundary interval between cars in a stream on the main street, at the appearance of which a car waiting on a secondary street can perform a crossing or merger maneuver.

The value of this interval is determined from the condition that it will be acceptable for more than 85% of drivers and is equal to $t_{br} = 6{,}5$ s.

In the main stream there are intervals between cars of different lengths, so t_m can appear several times larger than tbr. In this case, during a period of time, several vehicles of a secondary direction can pass. The number of cars of a secondary street that has passed through the main stream within one interval t_{br} depends on its duration.

The total number of all vehicles of a secondary direction that have traveled over the time interval $t_m > t_{rp}$, will give the crossing capacity for a given intensity of the main direction. Knowing the distribution function of intervals in the main flow [8], [9], it is possible to determine the number of intervals of different duration (t_{br}) for skipping the i-th number of cars and, consequently, the carrying capacity of the secondary direction by formula

$$N_{вт} = M \cdot e^{-m\Delta t_{ГР}} / (1 - e^{-m\delta t}) \qquad (2.6)$$

Where N_{sec} – is the maximum throughput of one lane of a secondary direction;

M – traffic intensity of cars along the main street in two directions;

e – base of the natural logarithm;

m – The mathematical expectation of the number of cars in a given diameter per unit time (per second) is determined by the formula

$$m = M / 3600 \qquad (2.7)$$

δt – Intervals between cars that exit at the intersection with a secondary street.

As the observations [8] show, δt varies within rather narrow limits from 5.3 to 2.8 s. For cars, δt = 3,6-2,8 s, which is typical for urban conditions. With the increase in the number of cars, δt decreases.

The capacity of the mains in the section of the stop line of the regulated nodes

The capacity of the main line in the section of the stop line is determined by the capacity of one strip, the number of lanes, the organization of traffic in the node, the regulating regime.

The capacity of a strip of streets and roads of regulated traffic is defined as the maximum number of vehicles passing along the strip (through the line - stop) depending on the conditions and organization of traffic for one hour in one direction while observing the conditions of traffic safety.

The conditions for the organization of movement are expressed in terms of the fraction of the time from the duration of the cycle allocated for the movement of vehicles in each direction in which the throughput is determined ($\frac{Tg}{T}$).

When calculating the capacity, two assumptions are made:

1) all cars passing through the intersection can be delayed in front of traffic lights;

2) all cars after switching on the green signal pass through the intersection with the same speed and equal intervals of time.

On this basis, to calculate the bandwidth of one lane, formula

$$N_{\Pi} = \frac{3600(t_g - t_a)}{T_c t_n} \tag{2.8}$$

где t_g – is the duration of the green traffic signal, s;

t_a – the time interval between the green phase of the traffic light and the stopping of the first car, s;

t_n time interval between cars when passing the stop line, s.

According to the results of observations t_a is is 1-3 s, it is recommended to take $t_a = 2$ s in the calculations.

The value of t_n for observations is 1-3 s for passenger transport, 3-5 s for freight traffic, it is recommended to take t_n = 2-3 seconds for a mixed flow.

Determining the loading levels of highways and nodes

The calculated throughput of each direction of movement in sections is compared with the actual traffic intensity (Nfact). The loading level is determined by the formula

$$Z = \frac{N_{fact}}{N_M} \leq 0,8 - 0,9 \tag{2.9}$$

The loading level should not exceed:

- at 2-stroke regulation - 0,9;
- with 3-stroke control - 0.85;
- with 4-stroke control - 0,8.

Violation of these conditions indicates the exhaustion of the capacity of the highway in the cross-section of the stop line or in the node as a whole.

The results of calculating the throughput and load levels of the regulated nodes are summarized in the table.

3.3. Example of calculating the throughput of an adjustable road junction

To calculate the capacity and loading level of the carriageway in the cross section of the stop line of the regulated node, the following initial data is necessary:

1. The actual or calculated intensity of motion in the units given in figure 17.

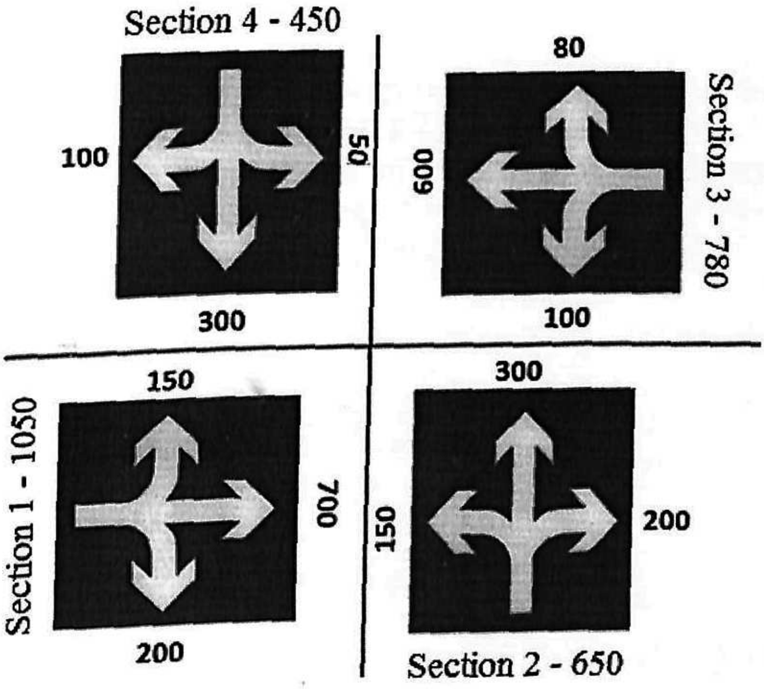

Figure 17

2. Distribution of flows of different directions along the lanes in figure 18.

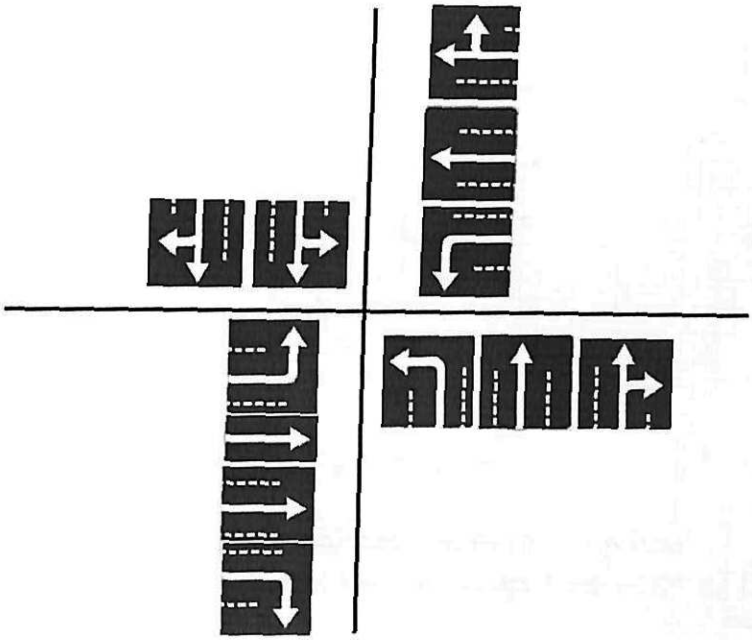

Figure 18

3. The number of lanes of the carriageway in the sections of the stop lines: sec. 1 - 4 lanes, sec. 2 and 3 - 3 lanes each, sec. 4 - 2 lanes.

4. Regulating mode and schemes of organization of movement by phases. Regulation is 2-stroke (t1 = 24 s, t2 = 14 s). T = 24 + 3 + 14 + 3 = 44 s.

Section 1

Throughput one lane

$$N_{\Pi} = \frac{3600(t_з - t_a)}{T_ц t_n} = \left(\frac{3600(24-2)}{44 \bullet 3}\right) = 600 \text{ u/h.}$$

Throughput of the 4-lane roadway $N_M = \eta N_n (n-2)$

Where η_n – is a coefficient that takes into account the throughput of the pivotal motion bands:

$$\eta_n = \frac{P + P_r + P_l}{P} \quad (3.0)$$

Where P_r – is the number of vehicles in the section making the right turn per hour.

In the absence of observational data η_n = 1,2–1,4.

$$\eta_n = \frac{P + P_n + P_л}{P} = \frac{1050 + 200 + 150}{1050} = 1{,}33$$

$N_м = 1,33 \bullet 600(4 - 2) = 1596$ u/h.

Section 2
Throughput one lane

$$N_П = \frac{3600(t_з - t_a)}{T_ц t_n} = \left(\frac{3600(14 - 2)}{44 \bullet 3}\right) = 327$$

Throughput of the 4-lane roadway $N_м = \eta N_п (n - 1)$

Where n – is the number of lanes in the section of the stop line

η_l – Coefficient taking into account the throughput capacity of the left-hand traffic zone:

$$\eta_l = \frac{P + P_l}{P} \tag{3.1}$$

Where P – is the total number of vehicles in the section of the stop line per hour;

P_l – The number of vehicles in the section, making a left turn per hour.
In the absence of observational data $\eta_л = 1{,}1–1{,}2$.

$$\eta_л = \frac{P + P_л}{P} = \frac{650 + 150}{650} = 1{,}23$$

$N_м = 1,23 \bullet 327(3 - 1) = 804$ u/h

Section 3
Throughput one lane

$$N_П = \frac{3600(t_з - t_a)}{T_ц t_n} = \left(\frac{3600(24 - 2)}{44 \bullet 3}\right) = 600$$

Throughput of the 4-lane roadway $N_м = \eta N_п (n - 1)$

$$\eta_l = \frac{P + P_l}{P} = \frac{780 + 100}{780} = 1{,}13$$

$N_м = 1{,}13 \bullet 600(3 - 1) = 1356$ ед/ч.

Section 4
Throughput one lane

$$N_{\Pi} = \frac{3600(t_з - t_a)}{T_ц t_n} = \left(\frac{3600(14-2)}{44 \bullet 3}\right) = 327$$

Throughput of the 2-lane roadway $N_{М} = \eta N_{п}$; $\eta = f(\alpha)$
Where η – is the coefficient reducing the throughput due to interference from the left-handed motion and depending on the fraction of the left rotation $\eta = f(\alpha)$.

η	2,0	1,65	1,60	1,55	1,50
α, %	0	10	20	30	40

$\alpha = 50/450 = 0{,}11$, $\eta = 1{,}65$;

$N_{М} = 1,65 \bullet 327 = 540$ u/h.

Regulation is 3-stroke, figure 19.
Tc = 20 + 3 + 10 + 3 + 14 + 3 = 53 s.

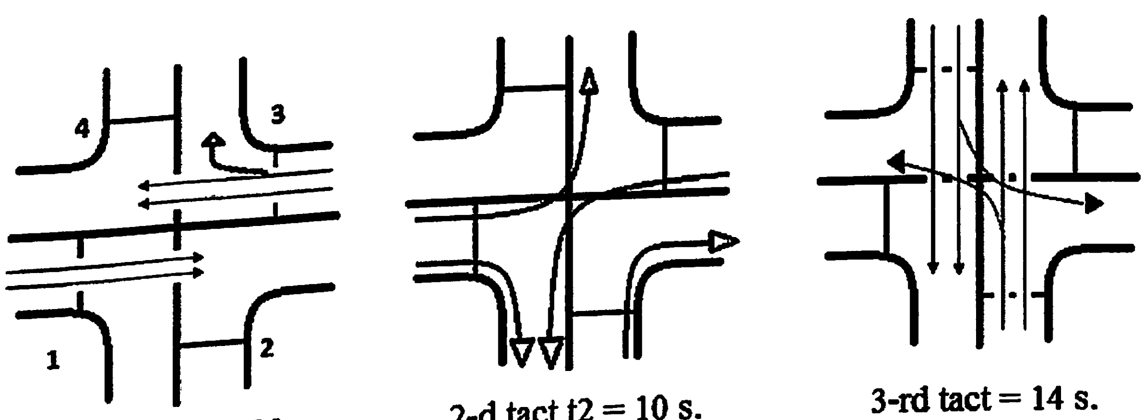

Figure 19. Distribution of flows of different directions along the bands with 3-stroke control

Section 1

$$N_m = N_1 + N_2 + N_3; \qquad (3.1)$$

Where N1 is the throughput of the bands allocated for skipping the direct direction;
N2 - the same, for the right-handed direction;
N3 - the same for left-handed direction.

$$N_1 = 2N_n; N_n = \frac{3600(20-2)}{53 \bullet 3} = 408 \text{ u/h}$$

$$N_1 = N_3 = \frac{3600(10-2)}{53 \bullet 3} = 181 \text{u/h}$$

$N_M = 2 \bullet 408 + 2 \bullet 181 = 1178$ u/h

Section 2

$$N_m = N_{1,3} + N_2;$$

$N_M = \eta N_n$; $\eta = f(\alpha)$;

$\alpha = 150/650 = 0{,}23$, $\eta = 1{,}58$;

$$N_n = \frac{3600(14-2)}{53 \bullet 3} = 272 \text{ u/h}$$

$$N_{1,3} = 1{,}58 \bullet 272 = 429 \text{ u/h}$$

$$N_2 = \frac{3600(10-2)}{53 \bullet 3} = 181 \text{u/h}$$

$$N_m = 429 + 181 = 610 \text{ u/h}$$

Section 3

$$N_m = N_{1,2} + N_3;$$

$$N_{1,2} = N_n(n-1) = \frac{3600(20-3)}{53 \bullet 3}(3-1) = 816 \text{ u/h}$$

$$N_m = 816 + 181 = 997 \text{ u/h}$$

Section 4

$N_M = \eta N_n$; $\eta = f(\alpha)$;

$\alpha = 0{,}11$; $\eta = 1{,}65$;

$$N_m = 1{,}65 \bullet \frac{3600(20-3)}{53 \bullet 3} = 448 \text{ u/h}$$

Calculation of loading levels of individual sections and the node as a whole is reduced to table 4.

Conclusions

With 2-stroke control, the node operates under normal conditions, has a capacity reserve.

With 3-stroke control, the throughput of sections 1, 2 and 4 is exhausted.

Table 5

Node	Section №	Directions of the movement	Actual intensity	2-stroke			3(4)-тактное		
	1	Right	200				181	1,10	>0,85
		Straight	700				816	0,86	>0,85
		left	150				181	0,83	<0,85
	Total in section		1050	1596	0,66	<0.9	1178	0,89	>0,85
	2	Right	200				181	1,10	>0,85
		Straight	300				429	1,05	>0,85
		left	150						
	Total in section		650	804	0.81	<0.9	610	1,07	>0,85
	3	Right	80				816	0,83	<0,85
		Straight	600						
		left	100				181	0,55	<0,85
	Total in section		780	1356	0.58	<0.9	997	0,78	<0,85
	4	Right	100						
		Straight	300						
		left	50						
	Total in section		450	540	0.83	<0.9	448	1,0	>0,85
	Total junction		2930	4296	0.68	<0.9	3233	0,91	>0,85

3.4 Simulation of intersection with forbidden left turn

At the intersections with the left turn, cars are hammered in a whole row 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, you can speed up the flow of cars and not take up a whole strip.

For the proposed solution variant, an application based on unity 3d was developed. The application is based on a simulated intersection with the prohibition of the left turn, with an animated traffic light and traffic patterns.

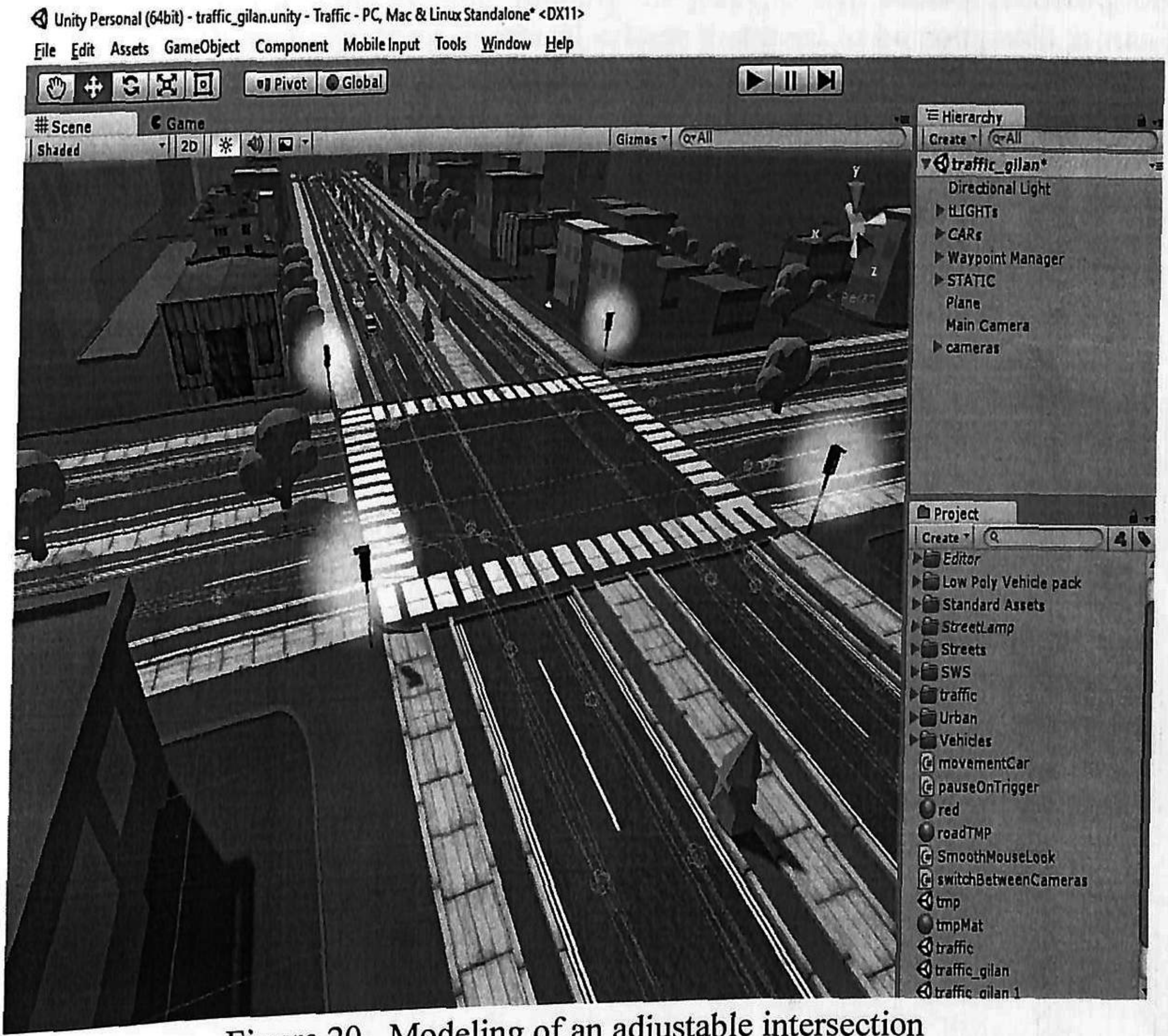

Figure 20. Modeling of an adjustable intersection

Unity3D is a powerful cross-platform 3D engine and a user friendly development environment. Easy enough for the beginner and powerful enough for the expert; Unity should interest anybody who wants to easily create 3D games and applications for mobile, desktop, the web, and consoles.

The Unity application is a complete 3D environment, suitable for laying out levels, creating menus, doing animation, writing scripts, and organizing projects. The user interface is well organized and the panels can be fully customized by dragging and dropping.

From figure 20 we can see the tools used:

Scene: This is where you will place any visual assets in your Unity environment. It will update in real-time when you are previewing the game. Note the manipulator on the top right; this allows you to switch between a number of standard views.

Hierarchy: This lists all the objects in the currently loaded scene, and any children they may have. Children are objects that can be thought of as subordinate to the parent object; wherever the top object moves, they'll follow, keeping the current offset they have to this object.

Game: When you're not actively running the game, it will show a rendering of how the game will look, ignoring graphical effects that need to be computed at run-time, from the point of view of the main camera. When you're previewing the game, you'll be playing through this window.

Project/Assets view: This is a list of all custom assets for our game, including graphical assets, sound, scripts (more on these later), prefabs (pre- assembled game objects), and much more. Our current game is currently using only one empty scene (titled "traffic_gilan ").

Inspector: Since we currently don't have any objects selected in the Hierarchy or the Project/Assets view, it's completely blank. The inspector allows us to look at and tweak individual settings of various game objects and assets, as well as adjust some global settings. The Inspector is content-sensitive and changes its parameters based on which game object/asset is selected. This is also a place to show you your project settings and preferences by choosing them from the Edit menu.

Graphical icons for moving the scene and its contents. The hand allows us to pan around the scene; when combined with other scene camera controls, Unity becomes very easy to navigate (see below). The icon on its right, which looks like four arrows, allows you to move a selected object around. We call this transforming the object. The next icon allows for rotation of the object, and the final one allows for uniform scaling of the object.

Playback bar. This allows us to play, pause, and stop running our game in the Unity editor. This is the quickest and easiest way to test and tweak the game.

The scene view is what allows you to look around and move the visual assets you import into Unity.

Figure 21. Modeling cars and their movement

3.4.1 Implementation

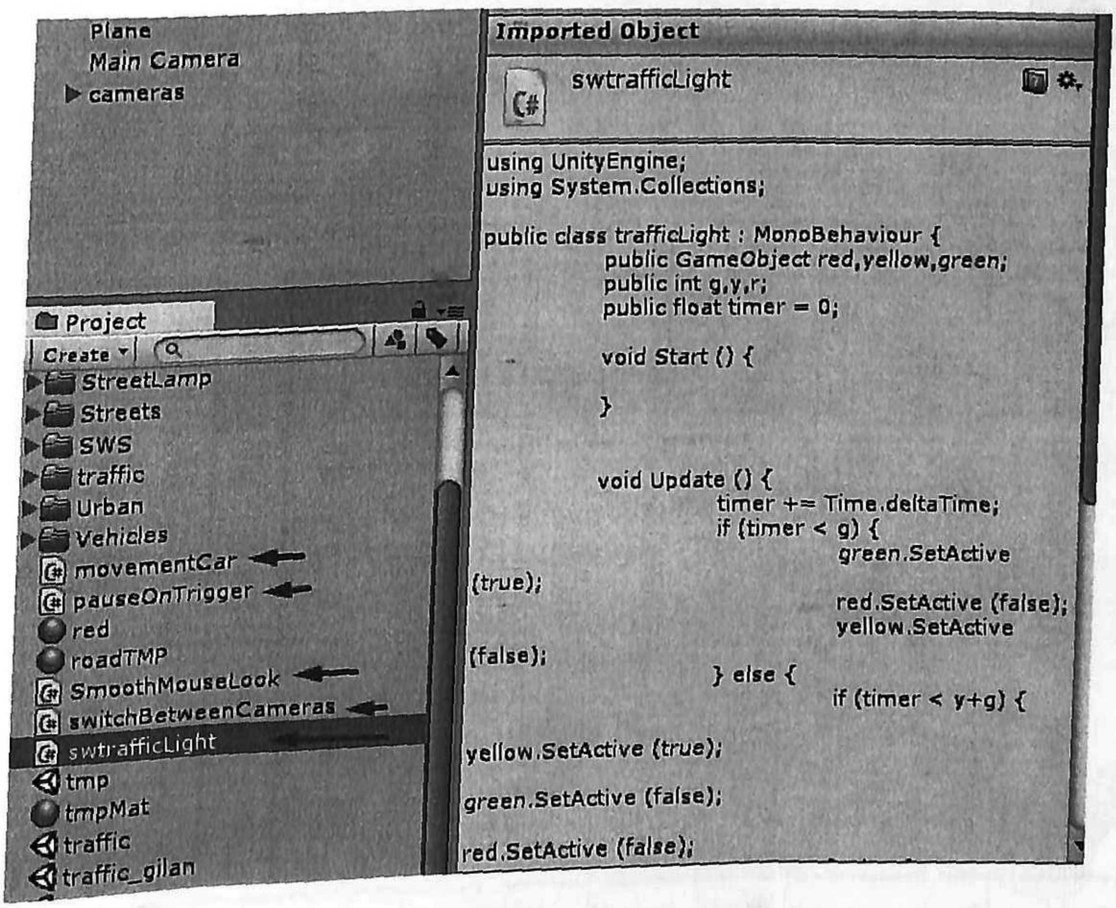

Figure 22. Used codes in C #

Stopping cars on red traffic light:

```
PauseOnTrigger.cs
using UnityEngine;
using System.Collections;
using SWS;
public class pauseOnTrigger : MonoBehaviour {
    public splineMove car;

    public GameObject red;
    public bool Variant2=false;
    private bool onRegion=false,onRegion2=false;
    // Use this for initialization
    void Start () {
    }
    // Update is called once per frame
    void FixedUpdate () {
        if (Variant2) {
            if (red.active && onRegion2) {
                car.Pause (5.0f);
            } else {
                car.Resume ();
            }
        } else {
            if (red.active && onRegion) {
                car.Pause (5.0f);
            } else {
                car.Resume ();
            }
        }
    }
    void OnTriggerEnter(Collider col){
        if (col.tag == "trafficRegion") {
            onRegion = true;
        }
        if (col.tag == "trafficRegion2") {
            onRegion2 = true;
        }
    }
    void OnTriggerExit(Collider col){
        if (col.tag == "trafficRegion") {
            onRegion = false;
        }
        if (col.tag == "trafficRegion2") {
            onRegion2 = false;
        }
    }
}
```

Animating and operation of traffic lights:

```
swtrafficlight.cs
using UnityEngine;
using System.Collections;
public class trafficLight : MonoBehaviour {
    public GameObject red,yellow,green;
    public int g,y,r;

    public float timer = 0;
    void Start () {
    }
    void Update () {
        timer += Time.deltaTime;
        if (timer < g) {
            green.SetActive (true);
            red.SetActive (false);
            yellow.SetActive (false);
        } else {
            if (timer < y+g) {
                yellow.SetActive (true);
                green.SetActive (false);
                red.SetActive (false);
            } else {
                if (timer < r+g+y) {
                    red.SetActive (true);
                    yellow.SetActive (false);
                    green.SetActive (false);
                } else {
                    timer = 0;
                }
            }
        }
        Debug.Log (timer);
    }
```

Car movement according to targets:

```
movementcar.cs
using UnityEngine;
using System.Collections;
public class movementCar : MonoBehaviour {
    public Transform[] targets;
    public Transform startPos;
    // Use this for initialization
    private NavMeshAgent nVAgent;
    public int indexOfTarget = 0;
    public string tagName;
    void Start () {
        this.gameObject.transform.position = startPos.position;
        nVAgent = GetComponent<NavMeshAgent> ();

    }
```

```
void FixedUpdate () {
    nVAgent.SetDestination (targets[indexOfTarget].position);
}
void OnTriggerEnter(Collider col){

    Debug.Log ("Find Next Target"+indexOfTarget.ToString());

    if (col.gameObject.tag == tagName) {
        if (indexOfTarget+1 < targets.Length) {
            indexOfTarget++;
      } else {
       this.gameObject.transform.position = startPos.position;
            indexOfTarget = 0;

}
}
```

Script which kept track of all the cameras in scene then i could switch cameras easily:

```
     switchbetweencameras.cs
     using UnityEngine;
using System.Collections;
public class switchBetweenCameras : MonoBehaviour {
    public Camera mainCamera;
    public Camera[] cameras;
    void Start () {
    }
    void Update () {
        if (Input.GetKeyUp (KeyCode.Keypad0)) {
            switchOffAllCameras ();
            mainCamera.gameObject.SetActive (true);

        }
        if (Input.GetKeyUp (KeyCode.Keypad1)) {
            switchOffAllCameras ();
            cameras [0].gameObject.SetActive (true);

        }
        if (Input.GetKeyUp (KeyCode.Keypad2)) {
            switchOffAllCameras ();
            cameras [1].gameObject.SetActive (true);

        }
        if (Input.GetKeyUp (KeyCode.Keypad5)) {
            switchOffAllCameras ();
            cameras [2].gameObject.SetActive (true);

        }
    }
    public void switchOffAllCameras(){
        for (int i = 0; i < cameras.Length; i++) {
            cameras [i].gameObject.SetActive (false);

        }
        mainCamera.gameObject.SetActive (false);

    }
```

Script where the camera will smoothly look around when the mouse is moved:

SmoothCamera.cs

```
using UnityEngine;
using System.Collections;
using System.Collections.Generic;

[AddComponentMenu("Camera-Control/Smooth Mouse Look")]
public class SmoothMouseLook : MonoBehaviour {
public enum RotationAxes { MouseXAndY = 0, MouseX = 1, MouseY = 2
}
    public RotationAxes axes = RotationAxes.MouseXAndY;
    public float sensitivityX = 15F;
    public float sensitivityY = 15F;
    public float minimumX = -360F;
    public float maximumX = 360F;

    public float minimumY = -60F;
    public float maximumY = 60F;
    float rotationX = 0F;
    float rotationY = 0F;
    private List<float> rotArrayX = new List<float>();
    float rotAverageX = 0F;
    private List<float> rotArrayY = new List<float>();
    float rotAverageY = 0F;
    public float frameCounter = 20;
    Quaternion originalRotation;
    void Update ()
    {
        if (axes == RotationAxes.MouseXAndY)
        {
            rotAverageY = 0f;
            rotAverageX = 0f;
            rotationY += Input.GetAxis("Mouse Y") * sensitivityY;
            rotationX += Input.GetAxis("Mouse X") * sensitivityX;
            rotArrayY.Add(rotationY);
            rotArrayX.Add(rotationX);
            if (rotArrayY.Count >= frameCounter) {
                rotArrayY.RemoveAt(0);
            }
            if (rotArrayX.Count >= frameCounter) {
                rotArrayX.RemoveAt(0);
            }
            for(int j = 0; j < rotArrayY.Count; j++) {
                rotAverageY += rotArrayY[j];
            }
            for(int i = 0; i < rotArrayX.Count; i++) {
                rotAverageX += rotArrayX[i];
            }
            rotAverageY /= rotArrayY.Count;
            rotAverageX /= rotArrayX.Count;
    rotAverageY = ClampAngle (rotAverageY, minimumY, maximumY);
```

```
        rotAverageX = ClampAngle (rotAverageX, minimumX, maximumX);
            Quaternion yQuaternion = Quaternion.AngleAxis (rotAver
ageY, Vector3.left);
            Quaternion xQuaternion = Quaternion.AngleAxis (rotAver
ageX, Vector3.up);
            transform.localRotation = originalRotation * xQuaterni
on * yQuaternion;
        }
        else if (axes == RotationAxes.MouseX)
        {
            rotAverageX = 0f;
            rotationX += Input.GetAxis("Mouse X") * sensitivityX;
            rotArrayX.Add(rotationX);
            if (rotArrayX.Count >= frameCounter) {
                rotArrayX.RemoveAt(0);
            }
            for(int i = 0; i < rotArrayX.Count; i++) {
                rotAverageX += rotArrayX[i];
            }
            rotAverageX /= rotArrayX.Count;
        rotAverageX = ClampAngle (rotAverageX, minimumX, maximumX);
        Quaternion xQuaternion = Quaternion.AngleAxis (rotAverageX,
 Vector3.up);
        transform.localRotation = originalRotation * xQuaternion;

        }
        else
        {
            rotAverageY = 0f;
            rotationY += Input.GetAxis("Mouse Y") * sensitivityY;
            rotArrayY.Add(rotationY);
            if (rotArrayY.Count >= frameCounter) {
                rotArrayY.RemoveAt(0);
            }
            for(int j = 0; j < rotArrayY.Count; j++) {
                rotAverageY += rotArrayY[j];
            }
            rotAverageY /= rotArrayY.Count;
            rotAverageY = ClampAngle (rotAverageY, minimumY, maxim
umY);
            Quaternion yQuaternion = Quaternion.AngleAxis (rotAver
ageY, Vector3.left);
            transform.localRotation = originalRotation * yQuaterni
on;
        }
    }
    void Start ()
    {
        Rigidbody rb = GetComponent<Rigidbody>();
        if (rb)
            rb.freezeRotation = true;
        originalRotation = transform.localRotation;
```

```
    public static float ClampAngle (float angle, float min, float
max)
    {
        angle = angle % 360;
        if ((angle >= -360F) && (angle <= 360F)) {
            if (angle < -360F) {
                angle += 360F;
            }
            if (angle > 360F) {
                angle -= 360F;
            }
        }
        return Mathf.Clamp (angle, min, max);
    }
}
```

CONCLUSION

As a result of the analysis, the causes were identified and the interconnections between the occurrence of traffic jams at a regulated intersection were identified. It was found that the most significant factors are: the discrepancy between the mode of operation of the traffic light object and the current and changing parameters of the traffic flow and weather and climatic conditions.

Based on the statistical analysis, analytical dependencies are obtained, which allow to predict the indicators of congestion occurrence and in accordance with the forecasts to make technical decisions.

A theoretical-methodical approach to predicting the occurrence of congestion is developed, based on mathematical statistics, which allows to perform a point forecast of the number of vehicles for a subsequent period of time.

It became clear that not all three-stroke and four-stroke traffic light controls the traffic and increases the throughput of the intersection, according to the received data it is revealed that in some cases this leads to a negative result.

At the intersections with the left turn, cars are hammered in a whole row and significantly reduce the throughput of the intersection. It was suggested to prohibit the left turn, and the cars to be launched to the right and forward, so that after driving to the gap in the dividing strip, wherever they turned left, you can speed up the flow of cars and not take up a whole strip.

An application was modeled and developed on the basis of the received traffic flow analyzes at a regulated crossroads.

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