Ministry of Science and Higher Education of the Republic of Kazakhstan
SDU University

Bagila Aitureyeva

Adaptive traffic control

THESIS

Presented in Partial Fulfillment for the
Degree of Master of Science in Mathematics
(degree code: 7M05401)
Department of Mathematics and Natural Sciences
Faculty of Engineering and Natural Sciences

Supervisor: **Nurlan Dairbekov, PhD**

Kaskelen, June 2024

SDU University
Faculty of Engineering and Natural Sciences
Department of Mathematics and Natural Sciences

Dean of Faculty of Engineering and Natural Sciences

Assistant Professor, Ph.D. Akhmedov Ramis

« 04 » 06 2024

Topic of the thesis:

Adaptive traffic control

Thesis submitted as part of the requirements for the award of the MSc in "7M05401-Mathematics"

Head of Department Birzhan Ayanbayev, PhD

Academic Supervisor Nurlan Dairbekov, PhD

Master student Bagila Aitureyeva,

Kaskelen, 2024

Declaration

I affirm that this work is my own and that all material sourced from other references has been correctly and fully acknowledged.

Bagila Aitureyeva

June 2024

Acknowledgements

Thank you to my supervisor N.Dairbekov for providing guidance and feedback throughout this project.

Dedication

I dedicate my dissertation work to my family and many friends.

Abstract

Adaptive traffic control is a key aspect of modern transport systems, aimed at optimizing the flow of vehicles, increasing safety and reducing congestion on the road infrastructure. This research abstract examines the concepts, methods and technologies of adaptive traffic control and their application to improve traffic efficiency. The paper discusses the basic principles of adaptive control, including the use of real-time traffic data, traffic flow forecasting, as well as methods for optimizing traffic light control and dynamic changes in road speed limits. Modern technologies, such as smart city systems and autonomous vehicles, and their impact on the development of adaptive traffic management are also discussed. The results of the study are of practical interest to city authorities, transport organizations and engineers seeking to make traffic more efficient, safe and sustainable. During the research, an article was published in an international collection on the topic "The implementation of adaptive traffic control system for reducing traffic congestion." Work was carried out on methodology, data collection and analysis. The experiments were carried out in a simulated environment The SUMO simulator for the intersection of K. Tulemetov and T. Utegenova streets, Shymkent. The SUMO simulator – Simulation of Urban MObility is a discrete-time platform for modeling traffic flows and is intended for assessing vehicle mobility models in the context of traffic management, and simulating assessment of traffic video surveillance systems. To simulate the transport situation in the simulator, data from video cameras close to the intersection are used.

Аңдатпа

Адаптивті қозғалысты басқару – көлік ағынын оңтайландыруға, қауіпсіздікті арттыруға және жол инфрақұрылымындағы кептелістерді азайтуға бағытталған заманауи көлік жүйелерінің негізгі аспектісі. Бұл зерттеу жұмысы адаптивті қозғалысты басқару тұжырымдамаларын, әдістері мен технологияларын және олардың қозғалыс тиімділігін арттыру үшін қолданылуын қарастырады. Мақалада адаптивті басқарудың негізгі принциптері, соның ішінде нақты уақыттағы қозғалыс деректерін пайдалану, көлік ағынын болжау, сондай-ақ бағдаршамды басқаруды оңтайландыру әдістері және жолдағы жылдамдық шектеулерінің динамикалық өзгерістері талқыланады. Сондай-ақ ақылды қала жүйелері мен автономды көліктер сияқты заманауи технологиялар және олардың бейімделген қозғалысты басқаруды дамытуға әсері талқыланады. Зерттеу нәтижелері жол қозғалысын тиімдірек, қауіпсіз және тұрақты етуге ұмтылатын қала билігі, көлік ұйымдары мен инженерлер үшін практикалық қызығушылық тудырады. Зерттеу барысында халықаралық жинақта «Көлік кептелісін азайту үшін қозғалысты басқарудың адаптивті жүйесін зерттеу» тақырыбында мақала жарияланды. Әдістеме, мәліметтер жинау және талдау бойынша жұмыстар жүргізілді. Тәжірибелер Шымкент қаласы, Қ.Төлеметов пен Т.Өтегенова көшелерінің қиылысы үшін. SUMO симулятор имитацияланған ортада жүргізілді. SUMO симуляторы – қалалық ұтқырлықты симуляциялау көлік ағындарын модельдеуге арналған дискретті уақыттық платформа болып табылады және қозғалысты басқару контекстінде көлік құралдарының ұтқырлық үлгілерін бағалауға және жол қозғалысының бейнебақылау жүйелерін бағалауды модельдеуге арналған. Тренажердегі көлік жағдайын имитациялау үшін қиылысқа жақын бейнекамералар деректері пайдаланылады.

Аннотация

Адаптивное управление трафиком является ключевым аспектом современных транспортных систем, направленным на оптимизацию потока транспортных средств, повышение безопасности и снижение загруженности дорожной инфраструктуры. Этот исследовательская работа рассматривает концепции, методы и технологии адаптивного управления трафиком, а также их применение для улучшения эффективности дорожного движения. В работе обсуждаются основные принципы адаптивного управления, включая использование данных о трафике в реальном времени, прогнозирование транспортного потока, а также методы оптимизации управления светофорами и динамического изменения скоростных режимов на дорогах. Также рассматриваются современные технологии, такие как системы умного города и автономные транспортные средства, и их влияние на развитие адаптивного управления трафиком. Результаты исследования представляют практический интерес для городских властей, транспортных организаций и инженеров, стремящихся сделать дорожное движение более эффективным, безопасным и устойчивым. За время исследования опубликована статья в международном сборнике на тему “ The implementation of adaptive traffic control system for reducing traffic congestion”. Проведена работа по методологии, сбора и анализа данных.

Эксперименты проводились в моделируемой среде SUMO симулятор для перекрестка улиц К.Тулеметова и Т.Утегенова г. Шымкент. Симулятор SUMO – Simulation of Urban MObility представляет собой дискретно-временную платформу для моделирования транспортных потоков и предназначен для оценки моделей мобильности транспортных средств в контексте организации дорожного движения, имитационной оценки систем видеонаблюдения за дорожным движением. Для моделирования транспортной ситуации в симуляторе использованы данные из видеокамер близлежащих к перекрестку.

Contents

1. Introduction

In the modern world, the problem of traffic management is one of the most urgent and difficult tasks, especially in cities with heavy traffic. This is caused not only by the increase in the number of cars on the roads, but also by the inefficiency of existing traffic management systems. In Kazakhstan, the problem of traffic management also remains relevant and requires urgent solutions.

The purpose of this work is to research and develop principles and methods of adaptive traffic management in Kazakhstan. To achieve this goal, it is necessary to perform the following tasks: to analyze the existing traffic management system in Kazakhstan, to study the principles and methods of adaptive traffic management, to consider the technical aspects of adaptive traffic management, to study the legal and organizational aspects of this system, as well as to identify the advantages and limitations of adaptive traffic management in Kazakhstan. Based on the conducted research, recommendations on the implementation of adaptive traffic management in Kazakhstan will be formulated.

The first chapter of the work is devoted to the analysis of the existing traffic management system in Kazakhstan. It will examine the current situation on the roads of Kazakhstan, the problems faced by drivers and pedestrians, as well as the main causes of traffic jams. There will also be a review of existing traffic management systems and their effectiveness. The second chapter will cover the principles and methods of adaptive traffic management. Various approaches to traffic management will be explored, such as the use of sensor systems, data analysis, forecasting and optimization. The advantages and disadvantages of each approach will also be considered. The third chapter is devoted to the technical aspects of adaptive traffic management. Various technical solutions used in traffic management systems will be considered, such as the synchronization of traffic lights, the use of cameras and sensors to monitor the traffic situation, etc. Technical requirements and opportunities for the implementation of adaptive traffic management in Kazakhstan will also be considered.

The fourth chapter will focus on the legal and organizational aspects of adaptive traffic management. The legal aspects of the implementation and operation of traffic management systems, such as legislation governing the use of technical means, as well as organizational aspects such as staff training and coordination of various organizations and services, will be considered.

The fifth chapter will be devoted to the advantages and limitations of

adaptive traffic management in Kazakhstan. The advantages of this system will be considered, such as increasing road capacity, reducing travel time and improving traffic safety. The limitations of this system will also be considered, such as the high costs of implementing and maintaining the system, as well as possible compatibility problems with existing infrastructure systems.

In the final chapter, recommendations will be formulated on the implementation of adaptive traffic management in Kazakhstan. Specific steps and measures that need to be taken for the successful implementation of this system will be proposed, as well as possible results and benefits from its use will be evaluated.

Thus, this work aims to explore and develop the principles and methods of adaptive traffic management in Kazakhstan. In the course of the work, an analysis of the existing traffic management system, principles and methods of adaptive traffic management, technical and legal aspects of this system, as well as advantages and limitations of its use will be considered. As a result of the work, recommendations will be formulated on the implementation of adaptive traffic management in Kazakhstan. The relevance of the study "Adaptive traffic management in Kazakhstan" is due to the growing problem of traffic congestion and inefficient traffic management in the country. With an increasing fleet and population, as well as the rapid development of cities, it is necessary to develop and implement new methods and technologies that can optimize car flows, reduce traffic congestion, and improve road safety. Adaptive traffic management is a personalized approach to traffic regulation based on the use of modern information and communication technologies, analytical algorithms, and a data collection system. The results of this study can be useful for government agencies and municipal administrations in developing and implementing effective measures to improve road infrastructure and reduce traffic jams, which in turn will lead to an improvement in the quality of life of citizens and the development of the country's economy.

In the work "Adaptive traffic management in Kazakhstan", the object of the study is the traffic management system on the roads of Kazakhstan, and the subject of the study is the processes and mechanisms used to optimize the movement of vehicles on the roads of the country. The main purpose of the study is to develop and implement an adaptive traffic management system that will effectively manage car flows, improve road safety, reduce traffic jams, and improve the quality of transport infrastructure in Kazakhstan. To achieve this goal, the study will include an analysis of existing traffic management systems, the development of models and algorithms for adaptive management, as well as conducting experiments and evaluating the effectiveness of the new system in practice.

2. Analysis of the existing traffic management system in Kazakhstan

2.1 The history of the traffic control system development

The traffic management system in Kazakhstan is an important element of ensuring the safety and efficiency of road traffic in the country. The development of this system began in the early 2000s and continues to the present day. In this section, we will look at the history of the development of the traffic management system in Kazakhstan, starting from its initial creation.

Initially, the traffic management system in Kazakhstan was introduced in the city of Almaty, which is the largest city in the country and has the most complex road infrastructure. In the early 2000s, a centralized traffic management system was created in Almaty, which included the installation of special traffic lights, video surveillance cameras, motion sensors and other technical means .

The traffic management system in Almaty has been developed considering international standards and advanced technologies. It made it possible to control and regulate traffic on the main roads of the city, optimize the operation of traffic lights depending on traffic density, as well as provide information about the state of roads and traffic jams in real time .

Subsequently, the traffic management system was expanded in other major cities of Kazakhstan, such as Nur Sultan (Astana), Shymkent, Aktobe and others. In each city, the system has been adapted to the specifics of the local road infrastructure and the needs of the population.

With the development of technology and the introduction of new innovations, the traffic management system in Kazakhstan has become more and more advanced. Innovations such as car speed detection systems, automatic license plate recognition, traffic jam and accident warning systems, as well as traffic violation warning systems have been introduced. The traffic management system in Kazakhstan also actively uses information technology to collect, analyze

and process traffic data. Special software products have been developed that allow you to quickly receive information about the condition of roads, predict possible traffic jams and take measures to prevent them.

However, despite significant achievements in the development of the traffic management system in Kazakhstan, it still faces several problems and limitations. For example, the insufficient number of video surveillance cameras and motion sensors in some areas of cities limits the capabilities of the traffic control and regulation system. In addition, some drivers do not follow the rules of the road, which leads to traffic jams and accidents.

In this regard, in recent years, Kazakhstan has been actively working to modernize and improve the traffic management system. The introduction of new technologies, an increase in the number of video surveillance cameras and motion sensors, as well as driver training and information campaigns on compliance with traffic rules - all this is aimed at improving the traffic situation in the country.

In conclusion, the traffic management system in Kazakhstan is an important tool for ensuring road safety and efficiency. It has gone through a long development path, starting from its initial establishment in Almaty and expanding to other cities of the country. However, there are problems and limitations that require further modernization and improvement of the system.

2.2 Main problems and limitations of the existing system

Traffic management is one of the most important tasks in the field of road infrastructure. The traffic management system in Kazakhstan has its own features and characteristics that require further study and analysis. This section will analyze the existing traffic management system in Kazakhstan, identify the main problems and limitations that are present today.

The main problems of the existing traffic management system One of the main problems of the existing traffic management system in Kazakhstan is the lack of full integration of various components of the system. Currently, there are separate traffic light control systems, speed control systems, video surveillance systems and others in Kazakhstan. However, these systems operate independently of each other and do not have the ability to exchange information. This creates significant problems in the planning and coordination of traffic.

Another problem is the lack of adaptability and flexibility of the existing traffic management system. Currently, most traffic lights in Kazakhstan operate according to a predetermined program that does not consider the current traffic situation. This leads to inefficient use of road infrastructure and the creation of traffic jams and congestion on the roads [1].

It should also be noted that the existing traffic management system in Kazakhstan has limited capabilities in the field of data collection and analysis. Despite the availability of some speed control and video surveillance systems, the collected data is not fully used to analyze and predict the traffic situation. This limits the capabilities of the traffic management system in making effective decisions and optimizing traffic.

Limitations of the existing traffic management system One of the main limitations of the existing traffic management system in Kazakhstan is the insufficient number of traffic lights on the roads. In many cities and towns of Kazakhstan, there is a shortage of traffic lights, especially at intersections with a large flow of traffic. This leads to the creation of traffic jams and congestion, increased travel time and dissatisfaction with road users.

Another limitation is the lack of modern technologies and equipment for traffic management. Currently, outdated traffic lights are used in Kazakhstan, which do not have the ability to manage and coordinate adaptively. The lack of modern equipment limits the capabilities of the traffic management system and makes it difficult for it to function effectively. It should also be noted that limited financial resources are allocated for the development and improvement of the traffic management system in Kazakhstan. Despite a significant number of problems and limitations, the state does not always allocate sufficient funds for the modernization and introduction of new technologies into the traffic management system. This hinders the progress and development of the system and increases the time needed to solve existing problems.

Thus, the analysis of the existing traffic management system in Kazakhstan allows us to identify the main problems and limitations that are present today. Lack of integration of various system components, lack of adaptability and flexibility, limited data collection and analysis capabilities, insufficient number of traffic lights, lack of modern technologies and equipment, limited financial resources - all these problems and limitations require attention and solutions. The development and improvement of the traffic management system in Kazakhstan is an urgent task that will improve the road infrastructure, reduce traffic jams and congestion, and improve road safety and comfort.

3. Comparative analysis with similar systems in other countries

3.1 Use of sensor systems to collect traffic data

The technical aspects of adaptive traffic management play an important role in effective traffic management in Kazakhstan. In this section, we will look at the use of sensor systems to collect traffic data, which are one of the key elements of adaptive management.

Sensor systems are a set of devices that are installed on roads and are designed to collect information about the state of traffic. They can be of various types, including sensors, cameras, radars, and other devices. Each type of sensor system has its own characteristics and advantages that can be used to collect traffic data [2]. One of the main advantages of sensor systems is their ability to continuously monitor traffic conditions on the roads. This allows operators to manage traffic in real time and take measures to prevent traffic jams and accidents. Sensor systems can also be used to collect traffic statistics, which can be used for analysis and planning of road infrastructure .

One of the most common types of sensor systems are sensors that are installed on the road surface. They can be of various types, including inductive sensors, optical sensors, and accelerometers. Inductive sensors work based on a change in the electromagnetic field that occurs when a car is passing. Optical sensors use laser beams to determine the speed and density of vehicles. Accelerometers measure the acceleration of a car and allow you to determine its speed and direction of movement [3]. Cameras are also widely used to collect traffic data. They can be installed on road signs, traffic lights or on special towers. The cameras can be equipped with computer vision systems that allow you to automatically process video and determine the number and type of vehicles on the road. This allows operators to quickly respond to traffic changes and take measures to regulate it.

Radars can also be used to collect traffic data. They work based on the reflection of radio waves from moving vehicles. Radars can be installed on road

signs, traffic lights or on special towers. They allow operators to determine the speed and density of vehicles and take measures to regulate traffic.

Sensor systems for collecting traffic data can be integrated into a single traffic management system. This allows operators to receive real-time traffic status information and take measures to regulate it. The integration of sensor systems also allows you to automatically analyze traffic data and make decisions based on adaptive control algorithms.

Sensor systems for collecting traffic data have their limitations. They may be affected by weather conditions such as rain, snow, or fog, which may reduce their accuracy and reliability. Also, the installation and maintenance of sensor systems requires certain costs, including the cost of purchasing and installing equipment, as well as its maintenance and repair.

In conclusion, the use of sensor systems to collect traffic data is an important aspect of adaptive traffic management in Kazakhstan. They allow operators to receive real-time traffic status information and take measures to regulate it. Various types of sensor systems, such as sensors, cameras, and radars, can be used to collect traffic data. However, they have their limitations, which must be considered when using them.

Traffic management is one of the key tasks in ensuring road safety and efficiency. Kazakhstan has a traffic management system that includes various infrastructure and information components. This section will analyze the existing traffic management system in Kazakhstan, as well as a comparative analysis with similar systems in other countries. Analysis of the existing traffic management system in Kazakhstan

The traffic management system in Kazakhstan is based on the use of various technologies and tools. One of the key elements of the system is a network of road signs and alarms that regulates the movement of vehicles on the roads. Road signs and signals provide drivers with information about rules and restrictions, as well as indicate the direction of travel.

Traffic lights are another important component of the traffic management system. Traffic lights regulate the movement of vehicles at intersections and ensure the safety and efficiency of traffic. In Kazakhstan, traffic lights are usually installed at intersections with heavy traffic or on dangerous road sections [4].

In addition, the traffic management system in Kazakhstan includes a video surveillance system. Video cameras are installed on the roads and allow you to monitor the situation on the road, identify traffic violations and take appropriate measures. Video surveillance can also be used to analyze traffic and optimize road infrastructure.

The traffic management system in Kazakhstan also includes information boards and panels that provide drivers with up-to-date information about the state of the road, traffic jams, accidents and other events that may affect the movement of vehicles. This information allows drivers to make decisions about

choosing a route and optimize their travel time.

Comparative analysis with similar systems in other countries To conduct a comparative analysis with similar systems in other countries, consider the experience of the USA, Germany, and Japan. The traffic management system in the USA includes a wide range of technologies and tools. In the USA, intelligent traffic management systems are actively used, which are based on the use of sensors, video cameras and other devices. These systems allow you to automatically adjust traffic lights, optimize traffic flow and provide up-to-date information to drivers. In Germany, the traffic management system is also based on the use of modern technologies. Dynamic traffic management systems are actively used in Germany, which make it possible to adapt the adjustment of traffic lights and speed to the current conditions on the road. This reduces traffic jams and improves road capacity.

In Japan, the traffic management system has also reached a high level of development. Artificial intelligence technologies are actively used in Japan to manage traffic. Artificial intelligence systems allow you to analyze large amounts of traffic data, predict its development and take appropriate measures to optimize traffic.

The traffic management system in Kazakhstan includes various infrastructure and information components that allow you to regulate the movement of vehicles on the roads. However, compared to similar systems in other countries, the traffic management system in Kazakhstan can be further developed.

To improve the traffic management system in Kazakhstan, modern technologies, and tools such as intelligent traffic management systems, dynamic traffic management systems and artificial intelligence systems can be introduced. These technologies will improve the efficiency and safety of traffic, reduce traffic jams, and improve road capacity.

In general, the development of a traffic management system in Kazakhstan is an important area for ensuring road safety and efficiency. The introduction of modern technologies and tools will improve the traffic management system and make traffic more comfortable and safer for all participants.

3.2 Application of communication technologies and information systems for data transmission

The technical aspects of adaptive traffic management play an important role in modern cities, especially in conditions of increased automobile traffic. With the development of communication technologies and information systems, new opportunities have emerged for data transmission and traffic management. In this section, we will consider the main technical aspects related to the use

of communication technologies and information systems for data transmission in adaptive traffic management. One of the main elements of adaptive traffic management is a data collection and transmission system. Various communication technologies are used for this purpose, such as radio channels, fiber-optic communication lines, cellular communications, and others. Each of these technologies has its advantages and limitations, therefore, depending on the specific conditions, various combinations of technologies are used to ensure reliable data transmission [5].

One of the most common communication technologies used in adaptive traffic management is cellular communications. With the help of cellular networks, it is possible to transfer data at high speed and provide real-time communication with mobile devices. Cellular communication also allows you to organize remote access to the traffic management system, which provides flexibility and efficiency in traffic management [6].

Fiber-optic communication lines are also widely used in adaptive traffic management. They provide high data transfer rates and reliable communications. Fiber-optic communication lines allow you to transfer large amounts of data, which is especially important when working with video surveillance and license plate recognition systems. In addition, fiber-optic communication lines are highly resistant to external influences such as electromagnetic interference and network overload [7].

Radio channels also play an important role in data transmission in adaptive traffic management. They provide wireless communication between various devices such as sensors, CCTV cameras, traffic lights and other elements of the traffic management system. Radio channels allow data to be transmitted over long distances and provide flexibility in the deployment of a traffic management system. Information systems are also used for data transmission in adaptive traffic management. They provide data collection, processing, and analysis, as well as provide information about the current state of traffic. Information systems allow traffic management operators to make informed decisions based on up-to-date data, which contributes to increased efficiency and road safety.

One of the main tasks of information systems in adaptive traffic management is to collect data on the current state of traffic. Various sensors and sensors are used for this, such as video cameras, motion sensors, traffic sensors, and others. The collected data is transferred to the central traffic management system, where it is processed and analyzed. Based on the information received, decisions are made on traffic light regulation, traffic flow management and other measures to improve traffic. One example of the application of information systems in adaptive traffic management is the intelligent transport system. This system integrates various traffic control elements such as traffic lights, sensors, and surveillance cameras into a single network, which allows traffic control operators to make decisions based on up-to-date traffic data. Such a system makes it possible to optimize the distribution of traffic flows, reduce waiting

times at traffic lights and improve the overall cross-country ability of roads.

Thus, the technical aspects of adaptive traffic management include the use of various communication technologies such as cellular communications, fiber-optic communication lines and radio channels, as well as the use of information systems for data collection, processing, and transmission. These technologies allow traffic management operators to make informed decisions based on up-to-date traffic data, which contributes to improving the efficiency and safety of traffic flows.

3.3 Development and implementation of intelligent traffic light control systems

The technical aspects of adaptive traffic management are key in the development and implementation of intelligent traffic light control systems. Adaptive traffic management is an innovative approach to traffic management, which is based on dynamic analytics and the use of modern information and communication technologies. One of the main advantages of adaptive traffic management is its ability to adapt to changing road conditions in real time. This is achieved using various sensors and data collection systems that constantly monitor traffic, weather conditions, time intervals and other factors affecting traffic.

One of the key elements of adaptive traffic management is an intelligent traffic light control system. This system is based on algorithms that analyze data received from sensors and make decisions about traffic light regulation in real time. The development and implementation of such systems require an integrated approach and consideration of many factors [8].

The first step in the development of an intelligent traffic light management system is the collection and analysis of traffic data. Various sensors are used for this purpose, such as video cameras, radars, inductive loops, and others. These sensors are installed at intersections and other road sections, and they continuously collect information about the number of cars, their speed, traffic density and other parameters [15].

The collected data is transferred to a central server, where it is analyzed and processed. Various machine learning and artificial intelligence algorithms are used for this purpose. These algorithms allow you to determine the optimal time intervals for the operation of traffic lights, as well as predict possible traffic jams and delays.

After analyzing the data, the system decides on the regulation of traffic lights. This may be a change in the duration of traffic lights, a change in the sequence of their operation, or other measures. It is important to note that these decisions are made in real time and may change depending on the current situation on the road.

An important aspect in the development of intelligent traffic light control

systems is their integration with other systems such as navigation systems, driver notification systems and others. This allows you to create a unified information environment in which all road users can receive up-to-date information about the condition of the road and make decisions based on this information.

The introduction of intelligent traffic light control systems requires certain technical solutions. It is necessary to ensure reliable communication between sensors, servers, and traffic lights. Wireless technologies such as Wi-Fi or cellular communications are often used for this purpose.

It is also important to ensure the reliability and safety of the system. Various technical solutions are used for this, such as server redundancy, data encryption, and other measures. In addition, the system must be able to operate independently of external factors such as power outages or network failures. In conclusion, the technical aspects of adaptive traffic management and the development of intelligent traffic light control systems play an important role in traffic optimization. These systems make efficient use of available resources and reduce traffic jams and delays on the roads. However, their development and implementation require an integrated approach, considering many factors and the use of modern technologies.

4. Principles and methods of adaptive traffic management

4.1 Basic principles of adaptive traffic control

The principles and methods of adaptive traffic management are an important tool for effective traffic regulation in Kazakhstan. Adaptive traffic management is based on the use of modern information and communication technologies and algorithms that allow you to consider the current situation on the road and make appropriate decisions to optimize the flow of vehicles.

The main principles of adaptive traffic management are flexibility, dynamism, and intelligence. Flexibility means the ability of the system to adapt to changes in the traffic situation and take appropriate measures to improve traffic. Dynamism implies continuous monitoring of the state of the road network and a quick response to emerging problems. Intelligence consists in the use of algorithms and models that allow you to predict and analyze traffic to optimize its flow [10].

One of the main methods of adaptive traffic management is the installation of intelligent traffic lights. These traffic lights are equipped with sensors that allow you to determine the current traffic intensity and, based on this information, adjust the operating time of the traffic lights. For example, if there is heavy traffic on one of the streets, then the traffic light on that street will show the green signal longer to ensure a smoother flow of cars.

Another method of adaptive traffic management is the use of a dynamic driver information system. This system provides drivers with up-to-date information about road conditions, traffic jams, accidents and other factors that may affect driving speed. This information allows drivers to choose the most optimal route and avoid traffic jams [4].

Another important method of adaptive traffic management is the use of an intelligent speed control system. This system allows you to automatically control the speed of cars based on the current traffic situation. For example, if there is high traffic on a road section, the system can automatically set a speed

limit to prevent traffic jams. Effective adaptive traffic management requires the joint work of government agencies, road services, telecom operators and other stakeholders. It is important to create a unified information system that will allow you to collect, process and analyze traffic data. Such a system should be open and accessible to all road users to ensure effective interaction and information exchange.

It is also necessary to conduct regular research and analysis of the state of the road network to identify problem areas and develop appropriate measures to improve them. For example, you can take pictures using drones or use satellite images to analyze traffic intensity on different sections of the road.

An important component of adaptive traffic management is the training of drivers and increasing their awareness of traffic rules. The more disciplined and attentive drivers are the less likely traffic jams and accidents are. To do this, you can conduct information campaigns, include special sections in driving schools and conduct training events for drivers. Thus, adaptive traffic management is an important tool for optimizing traffic in Kazakhstan. It allows you to consider the current situation on the road and take appropriate measures to improve traffic. The application of principles and methods of adaptive traffic management requires the joint work of government agencies, road services and other stakeholders. It is also necessary to conduct regular research and analysis of the state of the road network, train drivers and raise their awareness of traffic rules.

4.2 Methods of data collection and analysis for adaptive control

With an ever-growing fleet and an increasing number of road accidents, adaptive traffic management is becoming increasingly relevant. This system offers effective methods to improve traffic safety and efficiency, as well as reduce traffic jams and congestion. In this section, we will look at the basic principles and methods of adaptive traffic management, as well as methods for collecting and analyzing data necessary for the implementation of this system.

One of the basic principles of adaptive traffic management is continuous monitoring and analysis of the state of the road network. Various sensors and sensors are used for this purpose, such as CCTV cameras, radars, induction loops, etc. These devices allow you to collect information about traffic speed, traffic density, vehicle volume and other parameters that are necessary for making traffic management decisions [10]. The collected data is transmitted to the central management system, where it is analyzed and used to determine the optimal traffic management parameters. One of the methods of adaptive control is to change the time intervals of traffic lights depending on the current traffic congestion. For example, if there is a high traffic density on one road,

then the traffic lights on that road can be switched to longer green signals to ensure smoother movement of cars .

Another method of adaptive control is to change the direction of movement on certain sections of the road. For example, if there is high traffic on one road in one direction, then you can change the direction of travel for a while to reduce traffic jams and improve cross-country traffic.

Data analysis methods are also used to predict traffic and make more effective management decisions more accurately. For example, machine learning algorithms can be used to predict future traffic congestion based on historical data. This allows you to take appropriate measures in advance to avoid traffic jams and accidents.

Various technologies are used to collect data and transfer it to the central control system. For example, data from surveillance cameras and radars can be transmitted over the Internet, and data from induction loops can be transmitted over wired communication channels. There are also systems that use satellite communications to transmit data. It is important to note that for reliable operation of the system, it is necessary to ensure high data transfer speed and low latency.

In addition to collecting data on the current state of the road network, it is also important to analyze and use data on driver behavior. For example, you can analyze data on the speed of cars, the time of stops at traffic lights, the frequency of changes, etc. This data can be used to determine the optimal traffic management parameters and prevent accidents.

In conclusion, adaptive traffic management is an effective system that improves road safety and efficiency. It is based on the principles of continuous monitoring and analysis of the state of the road network, as well as on the use of various traffic management methods, such as changing the time intervals of traffic lights and changing the direction of movement. To implement this system, it is necessary to collect and analyze data on the current state of the road and the behavior of drivers. Various sensors and sensors are used for this, as well as data analysis methods such as machine learning algorithms. It is important to ensure reliable data transmission and use it to make optimal traffic management decisions.

4.3 Traffic modeling and forecasting for adaptive control

The principles and methods of adaptive traffic management are an important component of modern traffic management systems. They make it possible to optimize the use of available road resources and ensure more efficient movement of vehicles. This section will cover the basic principles and methods of adaptive traffic management, as well as traffic modeling and forecasting for adaptive

management.

One of the basic principles of adaptive traffic management is continuous monitoring and analysis of the state of the road network. To do this, various sensors and sensors are used that allow you to collect information about the current state of traffic. For example, with the help of CCTV cameras, you can determine the traffic density, the speed of cars and other parameters. This information is transmitted to the traffic control center, where it is analyzed, and decisions are made to optimize traffic .

Another principle of adaptive traffic management is decentralization and distribution of management functions between different levels of the system. Communication and control devices can be installed at the level of a road object (for example, an intersection), which allow you to automatically adjust traffic light signals depending on the current situation on the road. Thus, each object independently makes decisions on traffic regulation based on the information received . One of the methods of adaptive traffic management is the use of algorithms for optimal distribution of traffic flows. These algorithms allow us to determine the optimal distribution of traffic flows in different directions, considering the current traffic congestion and other factors. For example, if a traffic jam has formed on one road, the algorithm can redistribute traffic flows to other roads to avoid further deterioration of the situation .

For effective adaptive traffic management, it is necessary to be able to model and predict traffic. Modeling allows you to evaluate the effectiveness of various traffic management scenarios and choose the most optimal one. Various mathematical models are used to model traffic, which consider factors such as traffic density, car speed, duration of traffic light cycles, and others. Traffic forecasting allows you to predict the future situation on the road and take appropriate traffic management measures in advance.

One of the methods of traffic modeling and forecasting is the use of artificial neural networks. These networks are based on the principles of functioning of the human nervous system and can be learned based on available data. Neural networks can be used to predict traffic based on historical data and other factors such as weather conditions, holidays, and events. This allows you to predict the future situation on the road and take appropriate measures to manage traffic. In addition, other methods such as statistical models, econometric models, etc. can be used to model and predict traffic. These methods allow us to assess the relationship between various factors and traffic, as well as predict its future state.

Thus, the principles and methods of adaptive traffic management are an important tool for optimizing the movement of vehicles and ensuring the efficient use of road resources. Traffic modeling and forecasting allows you to predict the future situation on the road and take appropriate traffic management measures in advance. The use of various methods and models makes it possible to achieve more efficient and safe traffic on the roads of Kazakhstan.

5. Legal and organizational aspects of adaptive traffic management

5.1 Legislative and regulatory acts regulating traffic management

The legal and organizational aspects of adaptive traffic management are an important element of ensuring road safety and efficiency in Kazakhstan. To regulate and control traffic, there are various laws and regulations that define the rules and procedures for traffic management. One of the main legislative acts regulating traffic management in Kazakhstan is the Code of the Republic of Kazakhstan "On Roads and Road Activities". This Code defines the basic principles of traffic management, traffic rules and liability for violations of these rules. It also establishes requirements for road signs, traffic lights and other means of traffic regulation [9].

In addition to the Road Code, there are other laws, regulations and regulations that regulate traffic management in Kazakhstan. For example, the Rules of the Road, which establish rules and requirements for road users, as well as for road signs, traffic lights and other means of regulating traffic. These rules determine how drivers should behave on the road, which priority rules should be followed, and how the safety of pedestrians and other road users is ensured .

The organizational aspects of traffic management are also regulated by legislation and regulations. For example, the executive authorities in the field of road management and transport are responsible for the development and implementation of traffic management policies. They define measures to improve the traffic infrastructure, introduce new technologies and methods of traffic management, and organize training and training of specialists in this field .

Kazakhstan is also actively implementing adaptive traffic management, which is based on the use of modern technologies and systems that allow dynamically regulating traffic flows in real time. To do this, special programs and algorithms are being developed that analyze traffic data and make decisions

about traffic light regulation, speed changes and other parameters.

Kazakhstan also has regulations that regulate the use of technical traffic management tools. For example, GOST standards and Technical Specifications define requirements for traffic lights, road signs, video cameras and other devices used to control and regulate traffic. These standards establish requirements for the quality and reliability of equipment, as well as for its installation and operation.

In conclusion, the legal and organizational aspects of adaptive traffic management in Kazakhstan play an important role in ensuring road safety and efficiency. Legislative and regulatory acts define rules and procedures for traffic management, as well as requirements for technical means and systems used for this purpose. The development and implementation of adaptive traffic management is one of the priorities of the state in the field of road management and transport.

5.2 Organizational structures and traffic management processes

The legal and organizational aspects of adaptive traffic management play an important role in ensuring road safety and efficiency. In this section, we will consider the main legal and organizational structures, as well as traffic management processes in Kazakhstan.

One of the main tasks of legal regulation in the field of traffic management is to ensure the safety and comfort of traffic. In Kazakhstan, these issues are regulated by legislation, including the Civil Code of the Republic of Kazakhstan, the Law of the Republic of Kazakhstan "On Road Traffic", as well as several by-laws establishing norms and rules of the road .

The main regulations governing the organization and management of traffic in Kazakhstan are the Traffic Rules of the Republic of Kazakhstan. These rules establish general requirements for road users, the order of movement of vehicles, rules for stopping and parking, as well as other norms aimed at ensuring safety and smoothness of movement. Organizational structures and traffic management processes in Kazakhstan are divided into several levels. Traffic management activities are coordinated and monitored at the State level. The Ministry of Internal Affairs of the Republic of Kazakhstan plays a leading role in this process, which provides general guidance and coordination of the activities of the State Road Safety Inspectorate (Traffic Police) .

The Traffic police is the main executive body responsible for the control and supervision of compliance with traffic rules, as well as for the prevention and investigation of road accidents. It carries out registration and issuance of driver's licenses, registration of vehicles, as well as conducting an examination of the technical condition of vehicles. At the local level, the organization and

management of traffic is carried out by local governments, in particular, the departments of transport and communications of cities and districts. They are responsible for the organization of traffic on their territory, the establishment of traffic patterns, the placement of road signs and markings, as well as for the control and supervision of compliance with traffic rules.

Organizational traffic management processes include planning and developing measures to ensure road safety and efficiency. One of the important tools in this process is the development and implementation of traffic management programs, which include measures to regulate traffic, install alarm systems, organize parking lots and other activities. An important aspect of traffic management is the use of modern information and communication technologies. Automatic speed control, video surveillance and electronic monitoring of traffic violations are being introduced in Kazakhstan. These systems make it possible to automate control and supervision processes, as well as improve the efficiency and accuracy of recording violations.

In conclusion, the legal and organizational aspects of adaptive traffic management in Kazakhstan play a key role in ensuring road safety and efficiency. They include legislative norms and rules, organizational structures, and processes, as well as the use of modern information and communication technologies. The development and improvement of these aspects is an important task to ensure the safety and comfort of road users in Kazakhstan.

5.3 Interaction between various participants in the traffic management system

The legal and organizational aspects of adaptive traffic management play an important role in ensuring road safety and efficiency. The interaction between the various participants in the traffic management system is also of great importance to ensure smooth and safe traffic on the roads. One of the main legal aspects of adaptive traffic management is the development and implementation of relevant legislative acts and regulatory documents. These acts and documents should define rules and requirements for all road users, including drivers, pedestrians, cyclists, and other participants.

Kazakhstan has the Code of the Republic of Kazakhstan "On Roads and Road Activities", which regulates all aspects of traffic, including traffic management. This Code establishes rules and requirements for drivers, as well as rules for stopping, parking and other aspects of traffic management. The organizational aspects of adaptive traffic management include the development and implementation of appropriate organizational measures. One of these measures is the creation of special organizations responsible for traffic management on the roads. These organizations must be well organized and have sufficient resources to effectively manage traffic [14].

In Kazakhstan, there is a Ministry of Internal Affairs, which is responsible for the organization and control of traffic. This Ministry develops and implements various measures and programs to improve traffic management, including adaptive management. It also monitors and supervises compliance with traffic rules and punishes violators.

The interaction between the various participants of the traffic management system is a key aspect of the successful implementation of adaptive management. This includes interaction between drivers, pedestrians, cyclists, public authorities, special organizations, and other participants.

One of the ways to ensure effective interaction is the use of modern technologies and information systems. For example, smart city systems are being implemented in Kazakhstan, which allow collecting and analyzing traffic data in real time. This allows you to make more accurate traffic management decisions and prevent possible problems.

Interaction can also be carried out through training events and campaigns to raise awareness of traffic rules and adaptive management. This may include seminars, training, conferences, and other events aimed at sharing experiences and knowledge between different participants.

In general, the legal and organizational aspects of adaptive traffic management play an important role in ensuring road safety and efficiency. The interaction between the various participants in the traffic management system is a key factor in the successful implementation of adaptive management. This requires the development of appropriate legal acts and regulatory documents, the creation of special organizations for traffic management, the use of modern technologies and information systems, as well as training events and campaigns to raise awareness about traffic rules and adaptive management. All these measures contribute to improving road safety and efficiency in Kazakhstan.

6. Advantages and limitations of adaptive traffic management in Kazakhstan

6.1 Economic and environmental benefits of implementing adaptive management

Adaptive traffic management is one of the most effective tools for improving the flow of vehicles on the roads of Kazakhstan. It is based on the use of modern technologies and systems that allow you to automatically regulate traffic in real time. This makes it possible to improve road capacity, reduce delays and improve road safety.

Advantages of adaptive traffic management One of the main advantages of adaptive traffic management is its ability to respond to changes in traffic flow in real time. Traditional traffic management systems, such as traffic lights with preset signaling programs, cannot adequately respond to changes in traffic flow, which leads to delays and congestion. Adaptive traffic management makes it possible to optimize the use of road infrastructure, considering the current load and traffic needs [15]. Another advantage of adaptive traffic management is its ability to improve road safety. Adaptive traffic management systems can automatically respond to emergencies and optimize traffic around them. They can also provide information about the condition of the road and warn drivers about possible hazards such as ice or road work, which helps to reduce accidents.

Another advantage of adaptive traffic management is its ability to optimize the use of road infrastructure and reduce environmental stress. Adaptive traffic management systems optimize the flow of traffic, reducing delays and improving road capacity. This reduces the time spent by drivers on the road and, as a result, reduces emissions of harmful substances into the atmosphere.

Limitations of adaptive traffic management One of the main limitations of adaptive traffic management is its high cost of implementation and support.

The development and installation of adaptive traffic management systems require significant financial costs. In addition, the support and maintenance of such systems also requires additional resources and specialists.

Another limitation is the need for a modern infrastructure and technical base for the successful implementation of adaptive traffic management. For the effective operation of adaptive systems, it is necessary to have a communication network, sensors, surveillance cameras and other technical means. In some regions of Kazakhstan, access to such infrastructure may be limited, which makes it difficult to implement adaptive traffic management.

The economic benefits of implementing adaptive management. The introduction of adaptive traffic management can bring significant economic benefits for Kazakhstan. Optimizing the use of road infrastructure reduces delays and improves road capacity. This reduces the time spent by drivers on the road and improves the efficiency of vehicle use. This, in turn, helps to save fuel and reduce the operating costs of the fleet.

In addition, adaptive traffic management can lead to a reduction in accidents and damage to road infrastructure. Optimization of traffic and warning of possible hazards can reduce the number of accidents and improve road safety. This, in turn, reduces the cost of repairing and restoring road infrastructure. Environmental benefits of implementing adaptive management The implementation of adaptive traffic management can also bring significant environmental benefits. Optimization of traffic allows you to reduce emissions of harmful substances into the atmosphere. Reducing delays and improving road capacity reduces the time drivers spend on the road and, as a result, reduces vehicle emissions. In addition, adaptive traffic management can help reduce traffic jams and congestion, which also leads to a reduction in emissions of harmful substances. Optimizing the use of road infrastructure reduces the number of vehicle downtime and idling, which helps to save fuel and reduce CO_2 emissions.

Adaptive traffic management in Kazakhstan has several advantages and limitations. It allows you to optimize the use of road infrastructure, improve road safety and reduce the burden on the environment. However, for the successful implementation of adaptive traffic management, it is necessary to have a modern infrastructure and high financial costs. The introduction of such a system can bring significant economic and environmental benefits for Kazakhstan.

6.2 Technical and organizational constraints in implementing the system

Adaptive traffic management is an innovative system that uses modern technologies to optimize traffic on the roads. In Kazakhstan, the introduction of such a system has several advantages that can significantly improve the condition of the road infrastructure and ensure road safety. One of the main advan-

tages of adaptive traffic management is to increase the efficiency of using road infrastructure. The system can automatically adjust traffic lights, optimizing waiting time at intersections and improving road capacity. This helps to reduce congestion and improve traffic flow [12].

Another advantage of adaptive traffic management is the improvement of road safety. The system allows you to control the speed of cars and apply various measures to prevent accidents and traffic violations. For example, if speeding is detected, the system can automatically issue a fine or warn the driver about speeding.

Adaptive traffic management also helps to save time and resources. Thanks to the optimization of traffic on the roads, drivers spend less time overcoming traffic jams and achieve their goals faster. It also reduces fuel consumption and emissions of harmful substances into the atmosphere.

One of the important advantages of adaptive traffic management is its flexibility and adaptability to changing traffic conditions. The system can automatically respond to changes in traffic intensity, weather conditions and other factors, which makes it possible to effectively manage traffic in real time. Limitations in the implementation of an adaptive traffic management system in Kazakhstan.

However, despite all the advantages, the implementation of an adaptive traffic management system in Kazakhstan also has several technical and organizational limitations. One of the main technical limitations is the need for modern road infrastructure. The system requires special equipment, such as surveillance cameras, sensors, traffic lights with automatic control, etc. Some regions of Kazakhstan may lack the necessary infrastructure, which makes it difficult to implement an adaptive traffic management system.

Another technical limitation is the need for a high-speed Internet connection to exchange data between the various components of the system. In some remote regions of Kazakhstan, access to high-speed Internet may be limited, which may complicate the operation of the system.

Organizational limitations in the implementation of an adaptive traffic management system in Kazakhstan are related to the need for coordination and cooperation between various organizations and departments. For the successful implementation of the system, it is necessary to establish agreed procedures and protocols for interaction between road services, police, city authorities and other stakeholders.

Another organizational limitation is the need to train personnel working with the adaptive traffic management system. The implementation of the new system requires training and education of personnel so that they can effectively use all the capabilities of the system and respond promptly to emerging problems.

In conclusion, adaptive traffic management in Kazakhstan has several advantages, such as increasing the efficiency of using road infrastructure, improv-

ing road safety, and saving time and resources. However, the implementation of such a system also has technical and organizational limitations that must be considered when developing and implementing the system in Kazakhstan.

6.3 Experience and results of implementing adaptive management in other regions

Adaptive traffic management is an innovative system that allows you to effectively manage the flow of vehicles on the roads. In Kazakhstan, the implementation of this system has several advantages and limitations that should be considered when developing and implementing projects in this area.

One of the main advantages of adaptive traffic management in Kazakhstan is to increase traffic efficiency. The system allows you to optimize the flow of vehicles based on up-to-date traffic data, such as traffic density, speed, and traffic volumes. Due to this, it becomes possible to reduce traffic jams and reduce travel time for drivers.

In addition, adaptive traffic management contributes to improving road safety. The system provides information about the condition of the road and possible hazards, such as accidents or bad weather. This allows drivers to make the right decisions and avoid potential accidents.

Another advantage of adaptive traffic management in Kazakhstan is saving time and resources. The system allows optimal distribution of traffic flows, which reduces fuel costs and reduces traffic congestion. This, in turn, leads to a reduction in emissions of harmful substances into the atmosphere and an improvement in the environmental situation in cities.

However, the implementation of adaptive traffic management in Kazakhstan also has its limitations. First, this is due to the high cost of developing and implementing the system. Significant funding is required to install sensors, cameras, traffic lights and other equipment, as well as to train specialists who will operate the system. In addition, adaptive traffic management requires modern infrastructure and technical support. Not all roads in Kazakhstan are equipped with the necessary means of communication and data transmission, which may complicate the effective operation of the system. It also requires constant software updates and hardware maintenance to ensure the smooth operation of the system.

The experience and results of implementing adaptive traffic management in other regions of the world may be useful for Kazakhstan. For example, there are already successful projects in the United States and Europe to implement an adaptive traffic management system. Significant positive results have been achieved in these regions, such as reducing traffic jams, increasing road capacity, and reducing accidents.

In the USA, in the city of Los Angeles, an adaptive traffic management

system was introduced, which reduced travel time by 12% and reduced the number of accidents by 15%. Similar results have been achieved in other U.S. cities such as Seattle and Chicago. In Europe, an adaptive traffic management system has been implemented in Stockholm, Sweden, which has reduced travel time by 25% and reduced carbon dioxide emissions by 12%. Similar results have been achieved in other European cities such as London and Amsterdam. Thus, the introduction of adaptive traffic management in Kazakhstan has several advantages, such as improving traffic efficiency, improving safety, and saving time and resources. However, the limitations associated with high cost and the need for modern infrastructure should be considered. The experience and results of the implementation of the system in other regions of the world can be useful for the development and implementation of projects in Kazakhstan.

7. Recommendations for the implementation of adaptive traffic management in Kazakhstan

7.1 Identification of priority directions for the development of the traffic management system

Currently, problems related to traffic management are becoming more and more relevant in Kazakhstan. The rapid development of cities, an increase in the fleet, an increase in the number of road transportation and violations of traffic rules lead to traffic jams, delays, accidents, and other negative consequences. In this regard, the introduction of adaptive traffic management becomes necessary to effectively solve these problems.

Adaptive traffic management is a system based on the use of modern information technologies to optimize the movement of vehicles. It allows you to automatically regulate traffic flows, considering current road conditions, as well as provide information to drivers about the state of the road network, optimal routes, and travel time [15].

The implementation of adaptive traffic management in Kazakhstan requires addressing several key issues. First, it is necessary to create a modern infrastructure that will allow effective traffic management. This includes the installation of sensors, surveillance cameras, adaptive traffic lights, speed control systems and other automation tools.

The second important step is the collection and analysis of traffic data. To do this, it is necessary to develop special software solutions that will collect information about traffic speed, traffic density, number of cars and other parameters on the roads. This data will be used to determine optimal routes, calculate travel times, and make traffic management decisions. The third step

is to develop adaptive traffic management algorithms. These algorithms should consider not only the current situation on the road, but also predict its development. They must be able to adapt to changing conditions and make decisions that will reduce traffic jams, improve road capacity, and improve road safety. The fourth step is to develop a driver feedback system. This can be a mobile application or information boards on the roads that will provide drivers with up-to-date information about the state of the road network, optimal routes, and travel time. Such a system will allow drivers to make informed decisions and reduce travel time. The identification of priority directions for the development of the traffic management system in Kazakhstan is an important step for the effective implementation of adaptive traffic management. The priority should be the creation of infrastructure for traffic management. This includes the installation of sensors, surveillance cameras and adaptive traffic lights on major roads and intersections. It is also necessary to develop a speed control system that will regulate the speed of traffic depending on the conditions on the road.

The second priority is the collection and analysis of traffic data. To do this, it is necessary to develop software solutions that will collect information about traffic speed, traffic density, number of cars and other parameters on the roads. This data will be used to determine optimal routes, calculate travel times, and make traffic management decisions.

The third priority area for the development of a traffic management system is the development of adaptive management algorithms. These algorithms should consider not only the current situation on the road, but also predict its development. They must be able to adapt to changing conditions and make decisions that will reduce traffic jams, improve road capacity, and improve road safety.

The fourth priority is the development of a driver feedback system. This can be a mobile application or information boards on the roads that will provide drivers with up-to-date information about the state of the road network, optimal routes, and travel time. Such a system will allow drivers to make informed decisions and reduce travel time.

In conclusion, the introduction of adaptive traffic management in Kazakhstan is of great importance for solving problems related to traffic management. Recommendations for the implementation of this system include the creation of infrastructure, the collection and analysis of traffic data, the development of adaptive control algorithms and a driver feedback system. The identification of priority directions for the development of the traffic management system in Kazakhstan will effectively solve traffic-related problems and improve road safety.

7.2 Development of a plan for the implementation and phased development of the system

Adaptive traffic management is one of the key tools for solving problems related to road congestion and traffic congestion. In Kazakhstan, as in many other countries, problems with transport infrastructure are becoming more and more urgent, especially in large cities.

The purpose of this work is to develop recommendations for the implementation of adaptive traffic management in Kazakhstan, as well as to develop a plan for the implementation and phased development of the system. As part of this work, the current state of the road infrastructure in Kazakhstan, problems related to traffic management, and specific measures to improve the situation will be considered.

The current state of the road infrastructure in Kazakhstan The road infrastructure in Kazakhstan is experiencing serious problems related to congestion and traffic congestion. This leads to significant problems for residents and visitors to the country, as well as for the economy. Insufficient number of roads, lack of an effective traffic management system and improper planning of road works – all this leads to transport problems that need to be solved.

Problems related to traffic management in Kazakhstan. One of the main problems related to traffic management in Kazakhstan is the lack of an adaptive traffic management system. Currently, most traffic lights in the country operate according to a predetermined program, without considering the current situation on the roads. This leads to the irrational use of road infrastructure and increased traffic congestion.

In addition, the lack of an adaptive traffic management system makes it impossible to effectively regulate traffic in the event of accidents, road works or other emergencies. This leads to an even greater deterioration of the transport situation and creates inconveniences for drivers and pedestrians. Recommendations for the implementation of adaptive traffic management in Kazakhstan.

To solve the problems related to traffic management in Kazakhstan, it is recommended to implement an adaptive traffic management system. This system will effectively regulate traffic on the roads, considering the current situation and predicting changes in traffic.

The first step in implementing an adaptive traffic management system should be to analyze the current situation on the roads of Kazakhstan. This will allow you to identify the most problematic areas and develop a strategy for the implementation of the system.

The second step should be to develop a plan for the implementation and phased development of an adaptive traffic management system. The plan should include specific measures to install new equipment, train personnel and carry out the necessary technical work.

The third step should be the implementation of an adaptive traffic management system on selected road sections. During the implementation, it is necessary to test the system and make the necessary adjustments.

The fourth step should be the phased development of an adaptive traffic management system throughout Kazakhstan. This can be achieved by installing new equipment on additional road sections, as well as training personnel and carrying out the necessary technical work.

The introduction of adaptive traffic management in Kazakhstan is an important step to address the problems associated with road congestion and traffic congestion. The recommendations presented in this paper will allow us to develop a plan for the implementation and phased development of the system, which will lead to an improvement in the transport situation in the country. The implementation of an adaptive traffic management system requires a coordinated approach from government agencies, road services and other stakeholders. This is the only way to achieve success and ensure comfortable and safe traffic on the roads of Kazakhstan.

7.3 Measures for training and informing participants of the traffic management system

The introduction of adaptive traffic management in Kazakhstan is an important step in improving the traffic system and improving road safety. For the successful implementation of this system, it is necessary to consider several measures to train and inform participants in the traffic management system. Initially, to train participants in the traffic management system, it is necessary to develop special programs and courses that will cover all aspects of adaptive traffic management. These programs should be available to both professional road users and ordinary drivers [18].

Specialized training courses are required for professional participants in the traffic management system, such as traffic police and dispatchers. These courses should include training on the principles of adaptive traffic management, the use of special devices and software, as well as tactics of interaction with other participants in the traffic management system. For ordinary drivers, it is also necessary to conduct training programs that will focus on the rules of the road and the features of the adaptive traffic management system. These programs should include information on how to properly interact with adaptive traffic management devices, how to interpret signals and instructions, and how to act in case of emergencies.

However, the training of participants in the traffic management system should not be limited only to conducting courses and programs. An important aspect is to inform participants about the implementation of adaptive traffic management and its features. To do this, it is necessary to develop information

brochures, video materials, as well as conduct educational campaigns in the media and on road signs.

Information brochures and videos should contain detailed information about the principles of adaptive traffic management, its advantages, and capabilities. They should also include practical tips on interacting with adaptive traffic management devices and traffic rules.

Educational campaigns in the media and on road signs should be aimed at a wide audience and highlight the topic of adaptive traffic management from different points of view. They should show examples of successful implementation of the system in other countries, as well as talk about plans to implement this system in Kazakhstan.

It is also important to pay attention to informing the participants of the traffic management system about current changes in the operation of the system. To do this, it is necessary to install special information boards on the roads that will display the current situation on the roads, warn about possible problems and give recommendations on choosing the optimal route. Thus, for the successful implementation of adaptive traffic management in Kazakhstan, it is necessary to conduct training and inform participants of the traffic management system. This will improve the efficiency of the system, improve road safety, and reduce the number of accidents.

8. Conclusion

In conclusion of this work on the topic "Adaptive traffic management in Kazakhstan", it is possible to summarize the main results and conclusions obtained during the study. In this paper, an analytical assessment of the existing traffic management system in Kazakhstan was carried out. It was revealed that it has several disadvantages, such as lack of flexibility and adaptability to changing traffic conditions. This leads to problems of road congestion, traffic delays, increased accident rates and low efficiency in the use of road infrastructure.

To solve these problems, the principles and methods of adaptive traffic management were considered. They allow you to dynamically respond to changes in the traffic situation and optimize the distribution of traffic flows. The use of methods such as adaptive synchronization of traffic lights, intelligent traffic management systems and flow forecasting can significantly improve the efficiency of traffic management and reduce congestion problems. The technical aspects of adaptive traffic management were considered from the point of view of the necessary technical means and infrastructure. It was revealed that the successful implementation of adaptive traffic management requires the use of modern technologies such as video surveillance systems, motion sensors, communication, and data processing systems. Examples of successful implementation of adaptive traffic management in other countries were also considered, which allows us to conclude about its effectiveness and the possibility of its implementation in Kazakhstan.

The legal and organizational aspects of adaptive traffic management were considered from the point of view of the need to develop appropriate legislation and organizational measures for the successful implementation of this system. It was revealed that to successfully implement adaptive traffic management, it is necessary to develop regulations, identify responsible authorities and procedures for interaction between them. The advantages and limitations of adaptive traffic management in Kazakhstan were considered in terms of its potential effectiveness and possible obstacles to its implementation. It was revealed that adaptive traffic management can significantly improve the transport situation in the country, reduce congestion problems and improve road safety. However, for the successful implementation of this system, it is necessary to consider such factors as the high costs of implementing and maintaining the system, the need for personnel training and ensuring the reliability of technical means.

In conclusion, recommendations on the implementation of adaptive traffic management in Kazakhstan were proposed. These include the need to develop appropriate legislation, create responsible authorities and provide the necessary technical infrastructure. It was also noted that for the successful implementation of adaptive traffic management, it is necessary to conduct an information campaign among the population and staff training.

Thus, adaptive traffic management is an effective tool for optimizing the transport situation in Kazakhstan. Its implementation will reduce the problems of road congestion, improve road safety, and improve the efficiency of the use of road infrastructure. However, for the successful implementation of this system, it is necessary to consider all technical, legal, and organizational aspects, as well as provide the necessary support and training of personnel.

References

[1] Topchij, D. Technical science. *European research: Innovation in science, education and technology. P. 6.* url: https://internationalconference.ru/images/PDF/2015/EUROPEAN_RESEARCH_6_7_.pdf#page=7

[2] Batorshin, T. R., Safin, M. A. Analysis of automatic control systems using artificial intelligence. *International scientific and technical conference of young scientists of BSTU. VG Shukhov, dedicated to the 170th anniversary of his birth. – 2023. – P. 53.* url: https://elibrary.ru/download/elibrary_54392727_95189034.pdf#page=53

[3] Vasiliev, A. G. T-Comm. url: http://media-publisher.ru/old/pdf/Nom-2-2011-sait.pdf

[4] Gancheryonok, I. I. et al. Digital transformation in construction: Information modeling. *Edited by SV Kharitonchik and SI Akhmedov // Minsk-Samarkand: SamSU Publishing House. – 2021.* url: https://www.researchgate.net/profile/Olmos-Jurayev/publication/370680797_Ucebnik_cifrovizacia_stroitelstva111/links/645d1997fbaf5b27a4bde287/Ucebnik-cifrovizacia_stroitelstva111.pdf

[5] Borisevich, Ya. R., Pilkovsky, D. O., Prokopenya, E. S. Main directions of digital transformation in logistics and supply chain management. *Automobile. Road. Infrastructure.= Avtomobil'. Doroga. Infrastructure. – 2022. – No. 1 (31). – P. 10.* url: https://www.adi-madi.ru/madi/article/view/1082

[6] Borisevich, Y. R., Pilkovsky, D. O., Prokopenya, E. S. Car. Road. Infrastructure. *Car. Road. Infrastructure Founders: Moscow Automobile and Highway State Technical University (MADI). – No. 1.* url: https://elibrary.ru/item.asp?id=48339012

[7] Danko, E. T. Ministry of education and science of the republic of Kazakhstan non-profit joint-stock company "Almaty university of energy and communications named after GumarbeK Daukeyev". url: https://info.aues.kz/diploms/2020/ikitk/tkss/muratbay_AUES.pdf

[8] Gancheryonok, I. I. et al. Chief researcher of the republican unitary enterprise "Institute of Housing-NIPTIS named after SS Ataeva" Doctor of technical sciences, Prof. url: https://www.researchgate.net/profile/Olmos-Jurayev/publication/370580340_Ministerstvo_nauki_i_vyssego_obrazovania_Respubliki_Belarus/links/64566e7a97449a0e1a802a35/Ministerstvo-nauki-i-vyssego-obrazovania-Respubliki-Belarus.pdf

[9] Avdeyuk, O. A. et al. Innovative, information and communication technologies: Collection of proceedings of the XV International Scientific and Practical Conference. *Edited by S.U. Uvaysov–Moscow: Association of graduates and employees of VVIA named after prof. Zhukovsky, 2019, p. 548.* ISSN 2500-1248. url: https://publications.hse.ru/pubs/share/direct/315492199.pdf

[10] Dolgiy, I. D. Theoretical foundations, methods and means of developing integrated dispatch control and centralization systems based on intelligent technologies. *Rostov-on-Don: Abstract. dis.....doctor of technical. Sciences, 2012.* url: https://static.freereferats.ru/_avtoreferats/01005513668.pdf

[11] Ananchenko, I.V., Golenok, M.V. Adaptive design. *Fundamental and applied scientific research: Current issues. – 2020. – P. 59.* url: https://naukaip.ru/wp-content/uploads/2020/09/MK-879.pdf#page=59

[12] Ashchepkova, N. S., Chernov, Yu. V. Section 21. Information science and modeling of motion of a robot loader. *Head of the conference: Sokol II (Ukraine). – P. 29.* url: https://repository.kpi.kharkov.ua/bitstreams/779c2347-dd41-4d9d-bdef-4a089df0aafb/download#page=29

[13] Vasilyeva, M.V. et al. State regulation of foreign economic activity: Legal, personnel and organizational aspects. – 2021. url: https://elibrary.ru/item.asp?id=46265160

[14] Damaskin, O.V., Krasinsky, V.V. Modern terrorism: State and counteraction. *Scientific and practical manual/OV Damaskin, VV Krasinsky. – 2017.* url: https://viperson.ru/uploads/attachment/file/950519/posobie.pdf

[15] Eremeev, A. E. et al. BBK 72 (5 Kaz) VII International scientific and practical conference "Student." – 2020. url: https://kuam.edu.kz/sites/default/files/2020/nauka/stud_vesna/7/tom4.pdf

[16] Grebennikov, M.V., Lysenko, A.S., Ryzhkin, P.P. Traveling salesman problem in logistics. *International scientific and technical conference of young scientists of BSTU. VG Shukhov, dedicated to the 170th anniversary of his birth. – 2023. – P. 49.* url: https://elibrary.ru/download/elibrary_54240411_16164376.pdf#page=49

[17] Gusakov, V. Science 2018. Stages of growth. – Litres, 2022. url: https://books.google.com/books?hl=ru&lr=&id=uknUDwAAQBAJ&oi=fnd&pg=PA2&ots=woec8g7kK_&sig=hn9WsVYkNnIVzyGeUh0jzOixtqk

[18] Zenkina, S. A. Improving sales management of a regional Haval dealership center taking into account international experience (using the example of Avtoplus LLC).