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ԲԱՐՁՐ ՏԵԽՆՈԼՈԳԻԱՆԵՐԻ ՏԵՂԵԿԱԳԻՐ
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Տեղեկագիրը հրատարակվում է Ակադեմիկոս Ի.Վ.Եղիազարովի ջրային հիմնահարցերի և հիդրոտեխնիկայի ինստիտուտի, Հիդրավլիկական հետազոտությունների հայկական ազգային ասոցիացիայի, Երևանի կապի միջոցների գիտահետազոտական ինստիտուտի և Շուշիի տեխնոլոգիական համալսարանի կողմից: Հիմնադրվել է 2016թ.: Լույս է տեսնում տարեկան 4 անգամ:

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APPLIED BASICS OF BUILDING A SYSTEM OF ENERGY MANAGEMENT AT A HIGH-TECH ENTERPRISE

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Abstract

The introduction of energy-saving measures and technologies that improve economic efficiency has recently been one of the key drivers for the development of modern high-tech enterprises in recent years. Energy management is one of the systematic approaches to energy savings. Its implementation necessitates development and application of an introduction algorithm of energy management system the structure of which interconnects individual – organizational, economic and technical measures and technologies.

Key words: high-tech enterprise, energy saving, improvement of energy efficiency, energy management, energy management system, automation, energy audit.

Introduction

Improvement of the energy efficiency in industrial enterprises is currently one of the top priorities for the development of high-tech industries. Energy savings can significantly reduce the enterprise's costs for fuel and energy resources used in manufacturing processes, as well as the amount of harmful emissions and waste produced by the enterprise activities, assisting in the reduction of environmental risks associated with its operation. As a result, their economic efficiency improves significantly. Furthermore, the cost of production is reduced, as is the price for end users, which contributes to the company's increased market competitiveness.

At the same time, a systematic approach to the implementation of energy-saving measures and technologies is required to reduce the consumption of fuel and energy resources at all stages of production and achieve long-term results in improving the energy efficiency of enterprise.

Energy management is one of the most popular system approaches to energy savings in modern industry. It is a single interconnected set of measures, technologies, equipment and specialized software that is then consolidated into a single energy management system.

Conflict setting

The establishment of an energy management system is a costly endeavor that necessitates a significant investment of financial resources. The task force should create a unified algorithm for the implementation of such a system in order for it to be successful. Without such an algorithm, there is a risk of insufficient coordination among organizers,

inefficient investment spending and so on. This algorithm covers all stages of the system development, from strategic planning to the implementation of basic energy-saving technologies.

Research findings

The practical implementation of an energy management system necessitates the resolution of a number of rather complex organizational and technical issues. In this case, an important factor is their organic interconnection within the framework of the algorithm for the formation of an energy management system, which allows the most efficient use of the time, economic, technical and intellectual resources of an enterprise [1]. The development of such an algorithm should take into account the enterprise economic potential, the existing technological backlog in the field of energy conservation as well as the scale and specifics of its activities. Furthermore, when developing an algorithm, developers have the opportunity to perform preliminary efficiency calculations and analyze the parameters of the system being created, allowing them to identify the most important technologies and directions for improving energy efficiency of the enterprise in advance. The universal algorithm for the creation of an energy management system is shown below (Fig. 1).

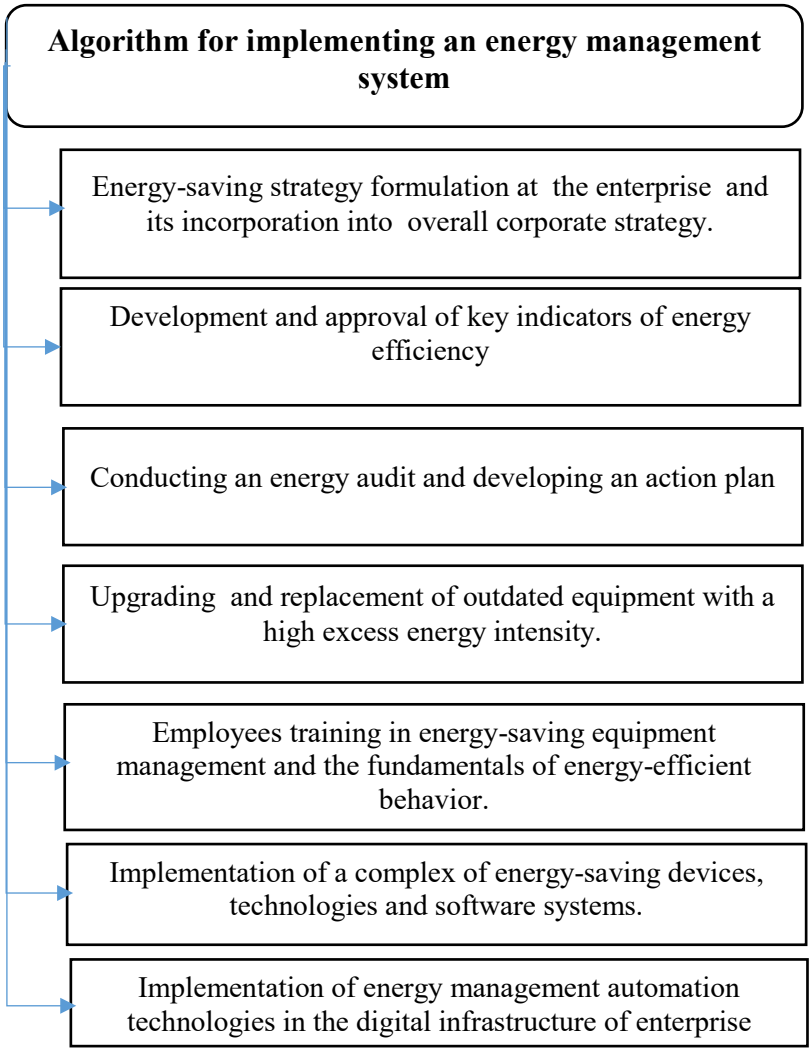

Fig. 1 The algorithm for implementing an energy management system at a high-tech enterprise

The algorithm for implementing an energy management system at a high-tech enterprise, as depicted in Fig. 1, consists of seven interconnected blocks (stages), the

distribution logic of which corresponds to the system approach. Let us take a closer look at each stage of this algorithm.

The first of these, depicted in Fig.1 is the stage 1, the formulation of an energy-saving strategy for the enterprise and its integration into its overall corporate strategy. The developed energy management system is one of the enterprise major subsystems and interacts closely with the majority of its technological subsystems, having a direct impact on the technological and economic efficiency indicators of the enterprise. At the same time, it plays an important role in the structure of the organizational and economic mechanisms of the enterprise.

Taking these factors into consideration, the primary task in its development is the development of an energy-saving strategy which will be implemented through the development of a system. This will allow it to determine its initial goal, tasks and priorities, as well as link them to available resources and target time parameters for completing individual tasks. The strategy itself should take into account the general economic priorities and performance targets of the enterprise [2]. Not only should responsible specialists be involved in the development of the enterprise, but so should heads of departments and representatives of the enterprise top management.

The second step at this stage is to incorporate the energy-saving strategy into the enterprise overall corporate strategy. Its implementation reflects, at the strategic planning level, the integration of the energy management system itself into the structure of the enterprise organizational and economic mechanism. The corporate key priorities and tasks of the strategy are interconnected with the enterprise performance targets and strategic objectives, directly influencing the development strategies of the production subsystem, technological development, innovative development and digital transformation among other things. At this stage, it is critical to conduct a thorough analysis of such relationships and mutual influence in order to anticipate possible changes in the strategic development trajectories of the remaining enterprise subsystems and optimize them as part of the adjustment of individual blocks of the corporate strategy.

The development and approval of key energy efficiency indicators (KenIs) is carried out based on the results of the development of the energy saving strategy. This stage represents the transition of work on planning the implementation of the energy management system from the strategic to the tactical level. The essence of energy-saving measures lies in their purposeful implementation, with mandatory fixation of the achieved level of energy efficiency growth. The fixation of the achieved energy effect enables objective indicators to be used to evaluate the effectiveness of specific technologies as well as the effectiveness of their implementation at a given enterprise.

To address this issue, it is proposed that a special type of indicator – key indicators of energy efficiency – be developed and implemented within the framework of the energy management system. These indicators are designed to evaluate the energy efficiency of various enterprise subsystems, stages of production, internal operations and processes. The goal of their implementation is a dynamic analysis and detailing of changes in the level of energy efficiency at all levels of the enterprise hierarchy, followed by an assessment of the effectiveness and contribution to the overall energy effect of individual energy-saving measures and technologies. The results of the analysis can be used for further optimization and technological development of the energy management system, as well as screening out and excluding objectivity because the effectiveness of their use is largely dependent on the level of professionalism, motivation and availability of the necessary energy-efficient

competencies among the employees themselves. In accordance with this, it is proposed that, in addition to the introduction of KenIs, key efficiency indicators (KefIs) for staff and employees responsible for energy conservation be introduced.

The main goal of introduction of KefI scorecard is to actively involve all employees responsible for its implementation in the operational processes of energy conservation management, by assigning specific KPI values to them based on their work profile. Employees for whom such indicators are developed include, first and foremost, heads of energy-saving departments, employees responsible for working with energy-saving equipment and specialized software, as well as specialists responsible for maintaining and modernizing the enterprise energy infrastructure. Thus, based on the coordinated implementation of KenIs and KefIs, the company's management gains access to a comprehensive toolkit for assessing both energy-efficient measures, technologies and equipment, as well as evaluating and analyzing the contribution of employees to overall energy efficiency of the company.

An energy audit and the development of a set of preparatory measures are the next steps in the formation of an energy management system. The primary tasks of conducting an energy audit (energy inspection) are to identify the current level of energy consumption of the enterprise, the main subsystems, sections and equipment with excessive energy intensity, the analysis of the technological state and its engineering and energy communications, the determination of the energy base line, and the selection and evaluation of promising energy-saving technologies, equipment, and integrated solutions.

An energy audit typically consists of two major stages: a cameral (cabinet) audit and an instrumental examination. The cabinet auditing entails gathering, systematizing and thoroughly analyzing all enterprise reporting documentation relating to various parameters of its energy consumption and individual energy technological indicators. Specialists form an initial picture of the general dynamics of the energy consumption of enterprise over the last five years based on the results of its implementation, identifying its most energy-intensive subsystems and production stages.

The second stage is an instrumental examination, which includes a site visit and direct hardware diagnostics and analysis of the enterprise buildings, energy and engineering communications. Instrumental energy audits are primarily concerned with measuring and assessing the consumption of energy carriers and steam, thermal imaging surveys, measuring water consumption in hot and cold water supply systems, multimetric surveys (assessment of the enterprise's internal environment parameters such as noise level, illumination, humidity and temperature, among others), measurement and evaluation of power supply systems and so on. Specialists use a variety of specialized equipment to conduct instrumental examinations, including noise meters, lux meters, thermal imagers, power consumption and power quality indicators, ultrasonic liquid flow meters, heat flux density meters and other similar devices.

Specialists systematize and analyze the main identified problems (for example, technical deterioration of enclosing structures and the formation of "cold bridges", high wear and tear of engineering communications and the presence of leaks in the hot water supply system, excessive power consumption from aspects of lighting systems, and so on) based on the summary data obtained from both stages of the energy audit, and develop technical solutions to eliminate them. Furthermore, based on the results of an energy audit, they can develop the most optimal configuration of preparatory measures aimed at comprehensively preparing the enterprise for the introduction of energy-saving technologies by obtaining

comprehensive data on the technical condition of the enterprise energy system, the types of equipment operating on its basis and the specifics of technological processes.

The fourth stage of a high-tech enterprise energy management system implementation algorithm is the modernization and replacement of obsolete equipment with a high excess level of energy intensity. The majority of the necessary reporting and analytical data for this stage's implementation is created during the energy audit stage.As experience shows, the use of outdated equipment with high excess energy intensity leads to the greatest unproductive energy losses compared to other negative factors. According to various scientists and experts, the share of losses from production equipment with no or low level of energy efficiency in various industries is up to 70-80%% of total losses and unproductive use of energy. This is explained by the fact that production equipment, due to the specifics of the technological organization, represents the largest share among the entire fleet of energy-consuming equipment operating on its basis.

One of the main reasons for the high energy intensity of production equipment is the use of outdated equipment at the enterprise, the design and creation of which took place back in those periods of time when its developers, in principle, did not have the task of reducing its energy intensity and increasing energy efficiency. The use of such obsolete equipment, unfortunately, is one of the fundamental problems of Russian industry associated with a difficult crisis in its development that occurred in the 90s of the last century.

The stage under consideration is one of the most expensive steps in implementing an energy management system, because modern energy-efficient production equipment is primarily produced in Western and East Asian countries, and individual CNC machines, machining centers, and industrial robots can cost tens of millions of rubles. At the same time, keep in mind that the necessary modernization of the enterprise's equipment fleet may necessitate the replacement of a number of such machines or machining centers.

It is in this context that the accuracy and depth of a previous energy audit is especially important, as it allows the ranking of individual equipment in terms of energy intensity and energy efficiency. This allows you to initially identify the most energy-intensive machines and other equipment that most significantly affect the level of energy efficiency of the enterprise's production system in order to focus on their modernization or replacement in the first place, while obtaining the maximum energy efficiency.

Energy management differs from other approaches to energy conservation in that it pays equal attention to the introduction of energy-saving measures and technologies as well as the participation of its employees in the processes of improving the enterprise energy efficiency, including both those responsible for energy conservation and other specialists and workers [4]. This is due to the significant impact of enterprise personnel on overall energy efficiency indicators, as the impact of introducing even the most modern energy-saving technologies can be leveled or reduced if employees lack the basic interest, motivation, and competencies to use these technologies in a timely manner and rationally handle the equipment entrusted to them.

As a result, the fifth stage of the energy management system implementation algorithm is to train staff on how to manage energy-saving equipment as well as the fundamentals of energy-efficient behavior. From the standpoint of system implementation, this stage should take place before the direct introduction of energy-saving equipment and technologies, so that by the time they are integrated into the enterprise's various technological systems, the

personnel have already acquired the necessary skills and energy-efficient competencies, as well as been trained in the fundamental principles of energy-efficient behavior.

The implementation of this stage is carried out within the framework of several successive sub-stages. The first of the sub-stages is the training in the principles and methods of energy efficiency improvement for representatives of the management of the relevant divisions (departments) of the enterprise, directly related to the management of the energy management system. The blocks of competencies they master include the basics of energy saving in industry, the selection, evaluation and analysis of energy efficient technologies, strategic and tactical planning in the field of increasing the energy efficiency of an enterprise, the practical fundamentals of managing an energy management system based on the development and analysis of its KPIs and KPIs of employees.

The second sub-stage is the training of specialized personnel responsible for the implementation, maintenance and technical support of individual components of the system. Such specialists may include power engineers responsible for the implementation and maintenance of the software components of the system, programmers, engineering and technical personnel, and specialists from equipment repair departments. Training of specialists from the above categories implies mastering not only the basic principles of energy saving, but also energy-efficient engineering competencies. Mastering these competencies, they subsequently acquire the necessary skills for comprehensive maintenance and support of various components of the system, learn the principles of managing its individual technologies and equipment, its technological modernization and scaling depending on the changes made to the energy saving strategy of the enterprise.

Employees and workers who do not interact directly with the energy management system are trained in the third sub-stage. The primary goal of their training is to gain knowledge in the areas of energy-efficient workplace behavior and the rational use of energy equipment available to them. As demonstrated by practice, successful implementation of this stage not only reduces energy losses at the enterprise due to the so-called “human factor”, but also creates conditions for the active dissemination of an energy-efficient culture among its employees and workers. It becomes an integral part of the overall corporate culture after being assimilated by them at the level of consciousness and motivation and is actively distributed, among other things and among new employees.

In fact, the sub-stages formed above represent three interconnected educational and practical circuits, the construction of which ensures the participation of representatives from all levels of the enterprise hierarchy in energy saving processes. The benefit of this approach is the establishment of numerous points of contact for the energy management system, as well as the participation of the vast majority of employees and workers in energy-saving processes.

Besides, from the standpoint of intra-organizational interaction, the implementation of such interconnected structures allows minimizing potential administrative and bureaucratic barriers in solving various problems of system development by combining managers and specialists from different departments within separate circuits. As a result, they can communicate about the joint implementation of energy-efficient competencies and the assimilation of energy-saving principles and ideology.

The practical implementation of the stage under consideration necessitates the involvement of experienced teachers, scientists and experts in the educational process. Given the scope of educational programs, even a medium-sized enterprise cannot complete this task with a single team of energy management system developers. The best approach to its

solution, in our opinion, is the organization of collaboration with leading technical universities, on the site of which there are educational units (chairs, departments) specializing in training specialists in the field of energy saving and digital transformation of the energy sector.

The sixth stage of energy management system implementation is the installation of a complex of energy-saving equipment, technologies and software systems. Members of the system formation team carry out the final design and modeling of its architecture within the framework of this stage, based on the data collected and systematized at the third stage of the algorithm based on the results of the energy survey. Taking into account the developed architecture, specific technologies and energy-saving equipment are chosen, and a roadmap for their implementation is created. On the basis of the roadmap, tactical and operational plans for their implementation are developed, including direct preliminary adjustments to the enterprise's existing power equipment and engineering and energy communications features. The suppliers of selected technologies, application software packages, integrated technological solutions and energy-saving equipment are determined by the system developers. Following this, the centralized purchase of the listed components of the software and hardware components of the energy management system is carried out.

Based on the above mentioned activities, the developers, in collaboration with technical specialists and experts from the manufacturing companies of the acquired technologies, integrated solutions, and equipment are gradually integrating it into the technological systems of the enterprise. First and foremost, the basic hardware and elements of the future hardware and software infrastructure of the energy management system are introduced. One of the critical conditions is the smooth implementation of these types of activities, ensuring their minimal impact on the current performance of the enterprise including forced shutdowns for the introduction of equipment for large sections of the power system of enterprise which may result in a halt in production. Furthermore, immediately following installation, all equipment is subjected to a stress testing procedure to determine the level of fault tolerance and, if necessary, to optimize the parameters and settings of its operation.

The next step is to deploy software and information systems that integrate the previously installed equipment into their structure. In today's energy management systems, software is just as important as the energy-saving equipment. It includes features like centralized data collection, systematization and analysis of all data on energy consumption and energy efficiency of enterprise technological systems, mechanisms for managing the energy management system itself and flexible configuration and optimization of its parameters.

Furthermore, on the basis of the deployed software infrastructure, a unified energy saving control center is being formed, allowing enterprise management and system management personnel to receive the entire amount of data on the enterprise's energy parameters in real time. This opens up numerous opportunities for flexible and operational analysis of thousands of processes at the enterprise level, significantly improving the quality of management decisions made as part of the regulation and optimization of the energy management system, taking into account the achievement of the target criteria for improving energy efficiency specified in tactical and operational plans.

The incorporation of energy management automation technologies into the enterprise digital infrastructure is the final step in the development of the energy management system. Its implementation is already taking place on the basis of fully deployed hardware and

software components, constituting a stage in their continued technological evolution in accordance with the Industry 4.0 methodology. At this stage, the primary activities are the technological interconnection of energy-saving equipment with the existing digital infrastructure of enterprise and the creation of end-to-end technological circuits. The creation of such circuits allows for the active influence of energy-saving equipment and technologies on the operating modes of production equipment and enterprise technological systems.

The active integration of software into the digital infrastructure of enterprise is the second step within the framework of the stage under consideration. The goal of this step is to create a common digital space in which the technological, economic and energy efficiency parameters of enterprise are interconnected. Traditional energy management systems have long been constrained by rigid administrative frameworks, and their operation has been carried out through sets of predetermined fixed procedures in the existing practice of energy conservation. As a result, their work processes were mostly isolated and separated from the main production and technological processes and industrial equipment of the enterprise. As a result, the effectiveness of such energy management systems has decreased, making it impossible for them to fully realize the energy-saving potential of enterprise.

In contrast, the integration of technologies and equipment of energy management system into the already existing digital infrastructure of the enterprise allows it to become a full participant in the main activities of enterprise, forming a projection of increasing energy efficiency within the framework of a common digital space. In practice, this means that the system can actively influence the processes of managing energy supply and energy savings at the enterprise. As a result, it can automatically implement adaptive control and regulation of the energy system of the enterprise in real time. It also gains the necessary degree of freedom and access level to respond as quickly as possible to various emergency situations, accidents, and equipment failures caused by power outages.

The algorithm for the development of an energy management system at a high-tech enterprise was considered above. One of the most important characteristics and competitive advantages of such systems over traditional approaches to energy savings is their ability to undergo digital transformation based on Industry 4.0 technologies and then be integrated into the enterprise's digital infrastructure. First of all, organic integration into its cyber-physical system which is the main technological platform that unites the entire complex of digital technologies and processes on its basis. Such integration opens up qualitatively new opportunities for automation and technological development of the energy management system itself.

Conclusion

The development of energy management systems is currently one of the most promising areas of modern energy conservation. Such systems are highly adaptable and scalable and they can incorporate a wide range of energy-saving technologies and methods for improving the energy efficiency of high-tech enterprises. At the same time, they are open systems in their structural essence and, as such, can be optimized and upgraded at any time without the need for a complete shutdown and shutdown of existing equipment.

The developed algorithm for building energy management systems has a high degree of universality and can be used to implement such systems in enterprises of various industries, regardless of their scale. It considers and arranges in a logical sequence all of the necessary

stages of creating a system, takes into account both technical and analytical measures,and works with enterprise personnel to form their energy-efficient workplace behavior.

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ԷՆԵՐԳԻԱՅԻ ԿԱՌԱՎԱՐՄԱՆ ՀԱՄԱԿԱՐԳԻ ՍՏԵՂԾՄԱՆ ԿԻՐԱՌԱԿԱՆ ՀԻՄՈՒՆՔՆԵՐԸ ԲԱՐՁՐ ՏԵԽՆՈԼՈԳԻԱԿԱՆ ՁԵՌՆԱՐԿՈՒԹՅՈՒՆՈՒՄ

Գոլով Ռ.Ս.

Մոսկվայի ավիացիոն համալսարան

Տնտեսության արդյունավետությունը բարելավող էներգախնայող միջոցների և տեխնոլոգիաների ներմուծումը վերջերս դարձել են ժամանակակից բարձր արդյունաբերական ձեռնարկությունների զարգացման առաջատար ուժերից մեկը:

Էներգիայի կառավարումը էներգախնայողության համակարգային մոտեցումներից մեկն է: Դրա իրականացումը անհրաժեշտ է դարձնում էներգիայի կառավարման համակարգի զարգացումը և կիրառումը, այն ներմուծման մի այնպիսի ալգորիթմ է, որի կառուցվածքը փոխկապակցում է անհատական, կազմակերպչական, տնտեսական և տեխնիկական միջոցները և տեխնոլոգիաները:

Բանալի բառեր: բարձր արդյունաբերական ձեռնարկատիրություն, էներգախնայող, էներգիայի արդյունավետության բարելավում, էներգիայի կառավարում, էներգիայի կառավարման համակարգ, ավտոմատացում, էներգիայի աուդիտ:

ПРИКЛАДНЫЕ ОСНОВЫ ПОСТРОЕНИЯ СИСТЕМЫ ЭНЕРГЕТИЧЕСКОГО МЕНЕДЖМЕНТА НА ВЫСОКОТЕХНОЛОГИЧНОМ ПРЕДПРИЯТИИ

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Одним из ключевых драйверов развития современных высокотехнологичных предприятий в последние годы стало внедрение энергосберегающих мероприятий и технологий, позволяющих повысить уровень их экономической эффективности. Одним из системных подходов к энергосбережению выступает энергетический менеджмент. Его реализация требует разработки и применения алгоритма внедрения системы энергоменеджмента, в структуре которой взаимоувязываются отдельные организационные, экономические и технические мероприятия и технологии.

***Ключевые слова*:** высокотехнологичное предприятие, энергосбережение, повышение энергетической эффективности, энергетический менеджмент, система энергоменеджмента, автоматизация, энергетический аудит**.**

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OPPORTUNITIES AND OBSTACLES OF DEVELOPMENT OF TOURISM IN THE REPUBLIC OF ARTSAKH

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Abstract

Tourism is one of the key spheres of socio-economic development of Artsakh. However, the worldwide Coronavirus pandemic of 2020 and the war unleashed against the Artsakh Republic in autumn of 2020 had a profound and irreversible impact on the entire economy of Artsakh, particularly on that of tourism. As a result, the movement of people and the opportunity to travel has been limited while the development of tourism is directly conditioned by the increase in the number of tourist visits and the income received from them. In the created difficult socio-economic and military-political conditions, the definition of directions for the restoration of the whole economy and tourism, the further development of the sphere, the development and implementation of effective and non-standard measures for the identification and elimination of existing obstacles are gaining great role and significance. The article presents the current state of the sphere and analyzes the main priorities for the development of tourism in the conditions of new realities in Artsakh. The existing challenges and problems facing tourism in Artsakh are identified and practical recommendations are presented to ensure competitive and sustainable development of tourism.

Key words: tourism, hotel business, payment balance, sustainable development, social-economic, Artsakh, crisis, marketing policy.

Introduction

Tourism is one of the fast growing industries in the world economy. It is of great economic importance to any country with tourism potential. Tourism is a field of business that meets the needs of the tourist, provides significant income to developing countries and regions. Tourism has become a source of income in many countries today as the significant part of the income goes to the state budget.

The development of the sector is characterized by the fact that by providing cash flows, it can have a significant impact on the economy and territorial development of any country, contribute to the creation of new jobs, improve infrastructure, i.e. hotels, roads, parks, food courts and entertainment places will be built and reconstructed. The prosperity of tourism can greatly contribute to the country's integration into international political, social and economic structures.

Conflict setting

Sustainable growth of tourism has a positive impact on the socio-economic situation in the country. Taking into account the current developments in the world economy, the Artsakhi economy should be able to rely as much as possible on those sectors of the economy for the development of which there are favorable conditions in the country. One of such branches is tourism. Tourism in Artsakh is one of the key spheres of socio-economic development of the country.

Like many mountainous countries, Nagorno-Karabakh is rich in recreational resources. The beautiful nature of our highlands, the unique landscapes, the historical and cultural rock-cut and hand-made monuments, the rich flora, peculiarities of the Armenian cuisine and the traditional hospitality of the people are important factors for the development of local and foreign tourism. In this context, tourism in the Republic of Artsakh was defined as a priority sector of the economy by the Law of the Republic of Artsakh on Tourism and by the relevant decree of the Government and recently it has become one of the most dynamically developing sectors in the country. However, the spread of coronavirus worldwide and the war unleashed against Artsakh since September 27, 2020 has had a profound and irreversible impact on the entire economy of Artsakh, particularly in the sphere of tourism. Unfortunately, after the 44-day war, along with the loss of the territories of Artsakh, about 2000 historical-cultural and architectural monuments, including 13 monastic complexes, 122 churches, 52 castles, 536 crossstones and 4 chapels remained in the territories occupied by the enemy and visiting a number of touristic places and sites of interest has became difficult or impossible.

As a result, the tourism sector faces new challenges and problems the solution of which requires systematized new approaches, events and action plans.

Research results

Existence of corresponding potential and the tendencies of tourism development registered in Artsakh recently prove the attractiveness of the branch, therefore, it is necessary to direct the available resources to the development of tourism directions which will maximally contribute to the progress of the tourism industry in Artsakh. Due to this, one of the promising directions of economic development by the Government of the Republic of Artsakh is tourism and significant steps were taken to improve the state regulation and management of the sector.

Due to the war and the coronavirus, the movement of people and the opportunity to travel has been restricted, while the development of tourism is directly conditioned by the increase of touristic visits and the income received from them.

In terms of tourist visits, high rates have recently been registered in Artsakh. According to the data of statistical service, 41963 foreign tourists visited Artsakh in 2019. By the way, the maximum growth of more than 70% was registered in the third quarter, when the CONIFA European Championship and the 7th Pan-Armenian Summer Games were held in

Artsakh which speaks of the positive direct impact of such events on the tourism. Evidence of this is the increase in the number of tourists visiting Artsakh in 2019 which exceeded the same rate of the previous year by 13,375 people or 46.8%, and this number has increased about 7.8 times compared to 2008 (Fig. 1).

It is obvious that the tension on border has an impact on the tourism sector which is evidenced by the decrease in the number of tourists in 2014. It should be noted that the number of foreign tourists visiting Artsakh in 2014 decreased by about 12% due to border tensions and 13961 tourists visited Artsakh in 2016. The decrease in the number was conditioned by the April four-day war which had a negative impact on the economy of Artsakh including the tourism.

It is obvious from Fig. 1 that compared to 2019, the number of tourists decreased by 39,519 people or 94.2%, in 2020 which was due to the negative impact of two factors: the KOVID-19 epidemic and the 44-day war between Azerbaijan and Karabakh.

According to official statistics, 2444 tourists from 45 countries visited the Artsakh Republic in 2020 instead of 41963 tourists from 93 countries of the previous year. The citizens of Russia, Iran, the USA, the Ukraine and France are in the first 5 countries visiting post- war Artsakh.The dominating majority are Russian citizens. Out of the total number of tourists, 1550 people or 63.4% visited the republic from the Russian Federation, 303 people or 12.4% from the Islamic Republic of Iran and 103 people or 4.2% from the United States of America (Table 1). It should be noted that the number of tourists arriving in Artsakh from the Republic of Armenia is not calculated or published, while the development of the tourism sector is definitely influenced by tourists from Armenia who stay at hotels, use street food, use public transport services and go shopping, etc. Therefore, in order to comprehensively assess the contribution of tourism to the economy of Artsakh, it is necessary to calculate the number of tourists from Armenia and the amount of money they spend here.

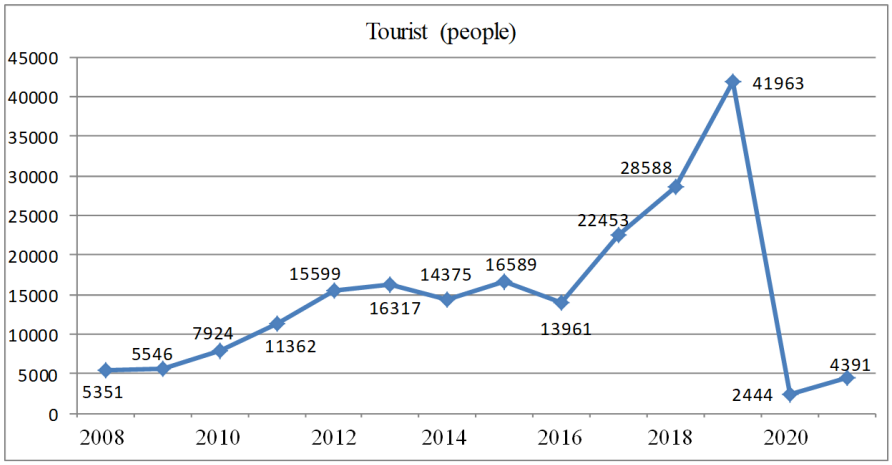

Fig. 1 Number of tourists visited Artsakh in 2008 - 2021

1447 foreign tourists visited Artsakh in January-June 2021. The geography of tourism has not changed during this period as the majority of visitors are citizens of Russia, followed by citizens of the United States, the Ukraine, France and Spain. The first major problem for foreign tourists is the problem of entry visa that is why the number of foreign tourists is small. The number of tourists has decreased by 30% in 2020 compared to the same period of June-January in 2019 and by 87% compared to the normal tourist period [1]. From January 1 to December 31, 2021, 4391 foreign citizens visited the Republic of Artsakh. This figure

increased by 45.6% compared to 2020 and decreased by 89.5% compared to the same period in 2019 [2].

Table 1

Tourist visits according to purpose and country [3]

	2018				2019				2020			
	Total	Purpose			Total	Purpose			Total	Purpose		
		Business	Personal			Business	Personal			Business	Personal	
			Business	Education			Leisure and rest	Education			Business	Education
Total	**28588**	**2940**	**25642**	**6**	**41 963**	**4965**	**36 998**	**-**	**2444**	**300**	**2144**	**-**
among which												
RF	15863	1562	14301	-	19 160	1696	17 464	-	1550	85	1465	-
The USA	3494	261	3232	1	7 527	521	7 006	-	103	13	90	-
France	1041	193	848	-	1 661	178	1 483	-	49	-	49	-
Germany	657	38	619	-	765	108	657	-	23	2	21	-
IIR	637	277	360	-	391	200	191	-	303	193	110	-
The Ukraine	540	106	434	-	526	104	422	-	81	-	81	-
Other countries	6356	503	5848	5	11933	2158	9775	-	335	7	328	-

Over the years, the picture remains unchanged in terms of the distribution of the purpose of the visit. 89.7% of tourists (25642 people) visited Artsakh for leisure and entertainment, 10.3% (2940 people) for business purposes and 6 people for educational purposes in 2018, 36,998 people or 88.2% visited for leisure and 4965 people or 11.8% for business purposes out of the total number of tourists in 2019. Of the total number of tourists visiting Artsakh 2144 people or 87.7% visited for leisure and 300 people or 12.3% for business purposes in 2020 (Fig. 2) [4].

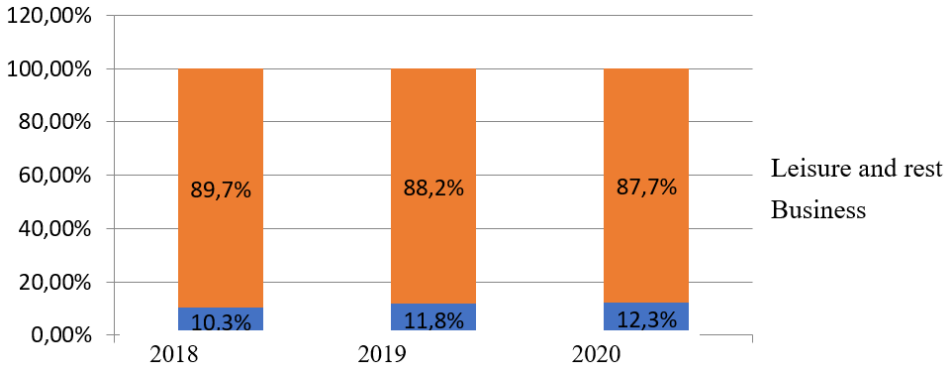

Fig. 2 Tourists visiting Artsakh according to their purpose in 2018-2020

Examining the balance of payments of the Republic of Artsakh which reflects the financial inflows and outflows from tourism, it should be noted that the negative balance of travel services amounted to 593.5 million drams in 2020 (against 532.0 million drams in 2019) or 1241.3 thousand dollars (credit - 3582.4 thousand dollars, debit - 4823.7 thousand dollars) [5]. It turns out that our population spends more abroad than foreign tourists [6] on goods and services in Artsakh. Thus, the amount received from tourists arriving in Artsakh

amounted to 3582.4 thousand US dollars in 2020, so the average cost of one tourist was 1465.8 US dollars (in 2017, each average tourist spent 104 US dollars, in 2018 - 80 dollars and in 2019 - 137 USD).

According to the Artsakh NSS, the volume of accommodation and public catering services comprised 16.3% of the total services in 2020 (12230.9 million drams of which the organization of accommodation - 575.7 million drams, the organization of public catering - 11655.2 million drams) of which 23.2% shared to Stepanakert and 76.8% - to other regions of Artsakh [7].

Due to the targeted state policy implemented in the sphere of tourism, a stable development of tourism was registered in Artsakh Republic. However, as in any industry, tourism is not without risks, one of which is the spread of a new type of coronavirus around the world the negative impact of which is obvious on the world economy. In the current uncertainty, not only incoming but also outcoming tourism suffers. Losses are registered by hotel-motel services, street and public food services and tourist services. They faced serious problems as most of them were based on tourism. First of all, many cultural monuments stayed in the territories which are currently occupied by Azerbaijan and then, due to the uncertainties of the post-war situation, there are fears that tourism will have significant problems in the coming years.

Nevertheless, despite the great losses, Artsakh has a great potential for tourism to be presented by rural tourism, ecotourism, hiking, cognitive, adventurous and cultural tourisms.

One of the tourist features of Artsakh is the event tourism which is mainly reflected in the festivals that have already become regular. Although no festivals were planned for 2021, tourist destinations continue by the TOURIST BUS program: visits to Nikol Duman House-Museum, Gandzasar and Amaras Monasteries etc. According to the 2020 program, one could visit Hunot Gorge historical and cultural reserve, Tigranakert and Togh Royal Palace. Now those destinations are lost and in other places the infrastructures are not yet ready to receive tourists.

Nevertheless, steps are being taken to meet new challenges and present Artsakh as an attractive tourist destination. In particular, safe tourist areas have been identified and activities are being done in the areas of rural and eco-tourism importance, for hiking and jeeping tours. Vank, Kolatak, Tsmakahogh, Tsaghkashat, Patara and Astghashen communities, Tnjri, Bovurkhan monastery hill and Amaras monastery directions have been selected and Gandzasar and Amaras are currently available from the old tourist attractions.

After the war, the Department of Tourism and Historic Preservation monitored to develop alternative tourism destinations. As a result, new perspective directions are offered: rich historical and cultural heritage, Patara village with natural monuments, Kachaghakaberd, Koshik desert, Hakobavank, St. Stepanos church and Bovurkhan monastery. A new walkway will be popularized: Patara-Meidan-Kachaghakaberd-Koshik desert-Kolatak which is already in use.

Tourism industry of Artsakh always has opportunities to develop, regardless of the time. What is lost through the war is irreplaceable. The tourism of Artsakh should be developed thanks to local tourism. Among the most popular tourist attractions in Artsakh were Tigranakert, Togh Royal Palace, Gtchavank, and, of course, Shushi, which, unfortunately, due to the military aggression against Artsakh, are now occupied by Azerbaijan. But as an alternative we have many resorts which in the past had few visits. They also have cultural significance among which are St. Hagoba Monastery of Kolatak, “Ptkesberk” monastery

complex of Ulubab, “Bri Yeghtsi” historical complex in Martuni region and other places. Very few people know Koshik desert, Havaptuk Monastery or Ruzan Fortress, the Monastery of Yeritsmankats etc. Now one of the directions of the expedition is Patara which has been turned into a recreation center in a post-war period.

Artsakh has new tourist centers which can be developed as a result of pursuing the right policy in the field of state support. The main goal of the tourism sector in 2022 will be to alleviate the crisis, to promote the pace of tourism development in Artsakh, to develop the tourism product of the Artsakh Republic and to popularize it in the target markets. The events implemented in the sphere will be aimed at:

- development of tourism infrastructure,
- the resumption and expansion of incoming tourist visits, especially from the Republic of Armenia, the Russian Federation, the countries of the European region, the Middle East,
-development of socio-economic and cultural life of the communities of Artsakh Republic through tourism,
- definition of competitive tourist regions, centers and tourist routes including them in sectoral development programs,
- implementing the image of Artsakh Republic as an attractive and safe country in the world tourism market through the implementation of an active and effective marketing policy in the field of tourism [8].

Conclusion

The development of the tourism sector in post-war Artsakh is hampered by the lack of confidence in potential tourists in terms of safety, status and security uncertainties which seriously undermines the entire economic field, investment climate and business ambitions. Ensuring security and clear information from the state will enable the business community to implement investment programs and activities.

The tourism result of Artsakh is diverse in terms of historical and cultural- cognitive and gastronomic-rural tourism creating and presenting interesting tourism results. It is necessary to create a new tourism product and we need the support of both the private sector and the state for its development.

The main goal of the popularization of the tourism product should be the promotion of the Artsakh brand and tourist attractions in the segmented and priority markets. It is necessary to carry out the work both in the digital domain and through the traditional marketing toolkit.

Tourism can contribute to the development of communities in various ways. Events or holidays organized by the community for tourists and the hospitality provided to them will contribute to the social activity of the community and the jobs created in the tourism sector and the resulting generated income will be an incentive for the local population not to leave the rural communities.

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ԱՐՑԱԽՈՒՄ ԶԲՈՍԱՇՐՋՈՒԹՅԱՆ ՈԼՈՐՏԻ ԶԱՐԳԱՑՄԱՆ ՀՆԱՐԱՎՈՐՈՒԹՅՈՒՆՆԵՐՆ ՈՒ ԽՈՉԸՆԴՈՏՆԵՐԸ

Հարությունյան Լ.Յու., Հարությունյան Ք.Ա.
Շուշիի տեխնոլոգիական համալսարան

Զբոսաշրջությունը հանդիսանում է Արցախի սոցիալ-տնտեսական զարգացման առանցքային ոլորտներից մեկը: Սակայն 2020թ. ամբողջ աշխարհում տարածված կորոնավիրուսի համավարակն ու 2020թ. աշնանը Արցախի Հանրապետության դեմ սանձազերծված պատերազմն իրենց խորն ու անդառնալի ազդեցությունն են թողել Արցախի ամբողջ տնտեսության, մասնավորապես զբոսաշրջության ոլորտի վրա: Արդյունքում սահմնափակվել է մարդկանց տեղաշարժը, ճանապարհորդելու հնարավորությունը, մինչդեռ

զբոսաշրջության զարգացումն ուղղակիորեն պայմանավորված է զբոսաշրջային այցելությունների և դրանցից ստացված եկամտի աճով: Ստեղծված բարդ սոցիալ-տնտեսական և ռազմաքաղաքական պայմաններում մեծ դեր ու նշանակություն է ձեռք բերում ինչպես ողջ տնտեսության, այնպես էլ զբոսաշրջության վերականգնման և ոլորտի հետագա զարգացման ուղղությունների նախանշումը և առկա խոչընդոտների բացահայտման ու դրանց վերացման արդյունավետ ու ոչ ստանդարտ միջոցառումների մշակումն ու իրականացումը: Հոդվածում ներկայացվել է ոլորտի առկա վիճակը, վերլուծվել են ԱՀ-ում նոր իրողությունների պայմաններում զբոսաշրջության զարգացման հիմնական առաջնահերթությունները: Բացահայտվել են ԱՀ զբոսաշրջության առջև ծառացած առկա մարտահրավերներն ու խնդիրները և ներկայացվել գործնական առաջարկություններ զբոսաշրջության մրցունակ և կայուն զարգացում ապահովելու համար:

Բանալի բառեր. զբոսաշրջություն, հյուրանոցային տնտեսություն, վճարային հաշվեկշիռ, կայուն զարգացում, սոցիալ-տնտեսական, ճգնաժամ, մարքեթինգային քաղաքականություն:

ВОЗМОЖНОСТИ И ПРЕПЯТСТВИЯ ДЛЯ РАЗВИТИЯ ТУРИЗМА В АРЦАХЕ

Арутюнян Л.Ю., Арутюнян К.А.
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Туризм является одной из ключевых сфер социально-экономического развития Арцаха. Однако пандемия коронавируса, распространенная по всему миру в 2020 г., и война, развязанная осенью 2020 г. против Республики Арцах, оказали глубокое и необратимое воздействие на всю экономику Арцаха, в частности, на сферу туризма. В результате передвижение людей и возможность путешествовать были ограничены, а развитие туризма напрямую связано с увеличением туристических потоков и получаемых от них доходов. В сложившихся сложных социально-экономических и военно-политических условиях большую роль и значение приобретает обозначение направлений для восстановления как всей экономики, так и туризма и дальнейшего развития сферы, а также разработка и реализация эффективных и нестандартных мер по выявлению существующих препятствий и их устранению.

В статье представлено нынешнее состояние сферы, проанализированы основные приоритеты развития туризма в условиях новых реалий в Республике Арцах. Выявлены существующие вызовы и проблемы, стоящие перед туризмом РА, а также представлены практические рекомендации по обеспечению конкурентоспособного и устойчивого развития туризма.

Ключевые слова: туризм, гостиничное хозяйство, платежный баланс, устойчивое развитие, социально-экономический кризис, маркетинговая политика.

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ISSUES OF MAMAGEMENT OF INVESTMENT RISKS IN THE SPHERE OF AGRICULTURE OF THE REPUBLIC OF ARTSAKH

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Abstract

In the current stage of post-war reconstruction of the economy of Artsakh, especially the agriculture which is its leading sector, the study of issues of investment attraction, their sketching and implementation of urgent steps for their solution have gained great importance and significance.

The process of attracting investments in Artsakh is subject to additional risk effects in the current new realities for the identification and the effective management of which the solution and identification of the problems of ensuring the development and application of modern and scientifically justified methods and approaches is signified.

Key words: investment risk, concept, methodology, financial loss, uncertainty, model, effectiveness.

Introduction

The issue of attracting investments in the Artsakh Republic has been and still remains one of the important issues of the economic policy implemented in the country. The organization of the process of securing the investments in the agricultural sector as leading branch of the economy has become urgent for the post-war recovery of the country's economy.

It should be noted that the ways to identify and solve the problems of improving the investment environment in the country are outlined in the priority reform programs of the Government of the Republic of Artsakh.

Conflict setting

Remarkable research and studies have recently been carried out in the native scientific-professional sphere dedicated to increasing the efficiency of investment risk management. They mainly address issues related to investment risk management in the financial –banking sector or the general level of the economy.

In the current period of post-war recovery of the Artsakhi economy, there is an urgent need to deeply study the issues of ensuring the efficiency of the management process of investment especially at the level of individual sectors of the economy.

Research results

The work on further improvement of the investment environment will be carried out in the following main directions:

- Awareness of a large number of foreign investors about the opportunities of investment environment in Artsakh,
- Study of the economy and also separate spheres gaining competitive advantages and developing target investment programs based on them,
- Regular monitoring of the progress of large investment projects, identification and settlement of problems hindering their implementation [1].

The investment project in the field of agriculture, like any other project, is accompanied by many potential threats in modern conditions: untested technologies, lack of resources, changes in the goals and objectives of the project etc. This is due to the fact that there is always the possibility of undesirable events. That is why investment risk management is one of the main processes when considering the possibility of investing capital.

Investment activity, like any economic activity, is subject to impact of various risks due to possible uncertainties in economic processes. Therefore, it is obvious that the effectiveness of the investment project, the attractiveness of the market including the existing risks can be extremely important for making investment decisions [2].

Investment risks can be defined as the possibility of changes in the level of return on investment, and the objects of risk in the case of investments are the property interests of the person investing in the project [3].

Risk management is very important for investors during investment activities which ensures consistent control over the investment process to minimize their possible unfavorable effects [4].

Investment risk management is a multi-step process to reduce or compensate the organization's losses in the event of an unfavorable situation. This process, first of all, presupposes an accurate assessment of the degree of possible risks, which will allow to form an objective picture of the extent of possible losses, to find ways to prevent or reduce them, and in case of impossibility of risk prevention to ensure their compensation.

Investment risk management can be defined as the identification, analysis and assessment of risks associated with investment activities. It is a set of unique measures aimed at reducing the negative impacts of risks arising from various factors (economic-political changes, price fluctuations, supply chain disruptions, etc.), acting as a link between weak and strong systems as well as a set of effective operations which includes all measures taken to avoid losses.

A review of the professional literature suggests that there are a number of methodological approaches of risk management that can be used to successfully mitigate the risks posed by the investment.

Summarizing we can present the model of risk management in Fig. 1.

The process of management of investment risks mainly includes the following stages:

- Identification of risks and analysis.
- Choice of ways of impacts on the risks based on assessment of their relative efficiency.
- Taking corresponding decisions.
- Direct impact on the risk.
- Clarification and control of the process of investment risk management [5].

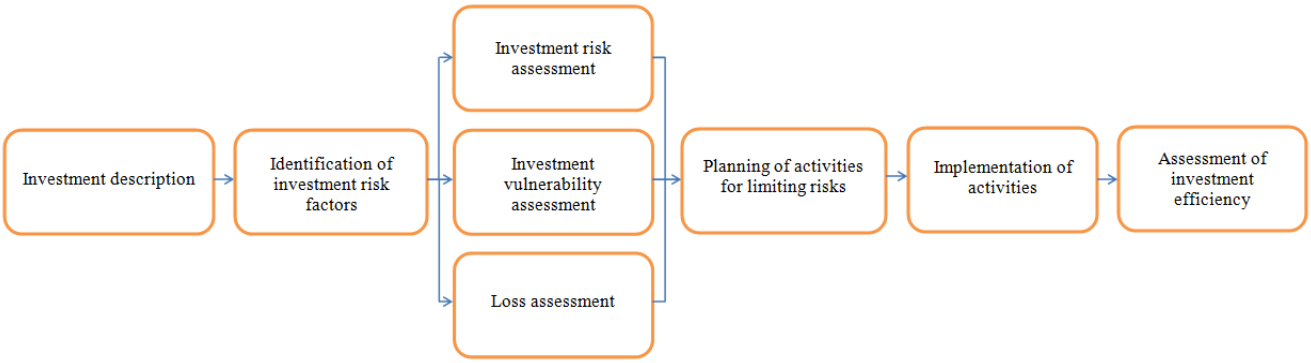

Fig. 1 Model of investment risk management

Touching up the methods for the management of investment risks, we should mention that that they are mainly four [6]:

- Method of risk prevention. This method suggests refusal from investment or transaction to exclude the risk which means no revenue for the investor.
- Method of risk withstanding which foresees the conscious undertaking of the risk by the investor.
- Method of neutralization of risk in the case of which all the measurements are taken to minimize the potential losses in systematized way.
- Method of risk transference which supposes the transfer of investment risk to other members of the market to decrease the risk.

Concerning the main tools applied for managing investment risks, we can say that they are mainly four:

- Risk distribution among the participants of investment,
- Insurance,
- Storage,
- Diversification,
- Hedging.

While taking any management decision, investment decisions are made in a risk or uncertainty. Therefore, the main tasks by investors when investing are accurate and the possible objective assessment of the current situation, early detection, assessment and management of risks. The latter are carried out at the initial stage of investment activity as a rule contributing to the formation of stable and sensible management decisions in the field.

The stages of the process of risk management are given below.

Defining the purpose supposes health care and family welfare in the event of income loss in case of death of a breadwinner as well as insurance protection of property, vehicles and other cases for a person, for example. The main goal for business entities is to ensure the existence of the organization in case of unforeseen circumstances (fire, theft, etc.).

Every risk-taking action is always purposeful as the lack of purpose makes the risk-taking decision meaningless. The purpose of the risk is to get the result you need. It can be profit, revenue and income**.**

Investigating the risk expresses in the consciousness of the risk by the business entity or individual. The latter goes on within social environment and is based on social practice as a rule.

Assessing the risk is the definition of seriousness of possible loss from the point of view of its amount.

Choosing the methods for investment risk management includes clarification of risk, prevention of loss and control, insurance and absorption. Choice of the method depends on the risk type and practically it meets simultaneous application of several methods of risk management.

Making up decisions define the further steps:

- **Interaction on the risk** and a comparison of efficiency of different methods of interaction take place in this stage.
- **Assessment of results** is done based on systematized and correct information system which enables to discuss the current losses and those actions the implementations of which will make loss prevention possible.

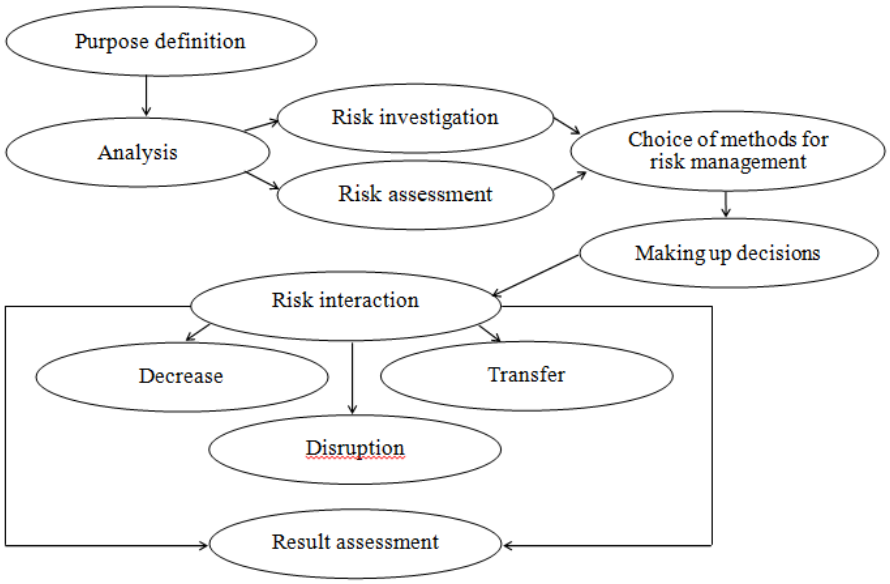

Fig. 2 Stages of the process of risk management

The risk management system is a rather complex unity the development and implementation of which is a comprehensive process. It is a multi-stage process of providing the initial conditions for the formation of the risk management system and the organization of primary procedures.

To ensure an effective solution to the problems posed by the risk management system, it must include the following key components without which targeted and effective operation of the risk management system is impossible. They are:

- Retrieving information and its processing,
- Analysis of risks by defining corresponding criteria to favorable factors for their existence and existence conditions and assessment of loss amounts as a result of risk,
- Development and implementation of processes of risk management in all stages,
- Analysis of admitted performances and their efficiency aimed at developing the offers.

In order to ensure the effectiveness of investment risk management in the current conditions it is necessary to take into account the circumstance of conceptual approaches to the organization of this process.

Three main concepts are currently distinguished which form the basis of risk management system in terms of the purpose of risk management:

- Concept of applicable risk,
- Concept of decreasing risk (zero risk),
- Concept of balance (obtaining balance between risk and investment profit) [7].

Meanwhile, the expediency of applying the third concept is substantiated as it allows to increase the efficiency of risk management due to the fact that during the risk management the perspectives of the development of organization will be related to the influence of external and negative internal risk factors and the peculiarities of investment projects will be taken into account [8].

Within the framework of the mentioned main concepts, scientific directions (approaches) are distinguished which differ in their content, in the accuracy of the methods of influencing the risk, in the tools for analysis as well as in the possibility of calculating the subjective attitude towards the risk. They are:

- Approaches based on subjective perception of risk (concept of calculating subjective perception of the person taking decisions over risk (PTD)),
- Theoretical- possible approaches,
- Unclear multiple approach (based on the theory of unclear multiple approach),
- Value approaches (oriented to application of market cost of financial tools in risk management) [9].

The research conducted by us among individual business entities engaged in agricultural activity in the current year shows that the process of investment risk management in Artsakh is not organized with the required depth and required methodology. These issues are reflected in the business plans for including financial means from banks or investment funds taking into account non-comprehensive and modern professional approaches.

Conclusion

A number of summaries and conclusions can be made based on the study of scientific-theoretical and practical materials on investment risk management.

First of all, it should be noted that a complete and scientifically substantiated methodology of investment risk management has not yet been developed by the relevant authorities both in the Republic of Armenia and in the Republic of Artsakh.

The need to improve the risk management process of the Artsakhi economy, particularly in the field of agriculture as its important part in the conditions of modern realities is conditioned, first of all, by external factors, undesirable developments in the military-political situation, internal and external inflationary pressures, imperfect legislative regulations and especially by the absence of methodological developments by authorized bodies.

Banking institutions, credit organizations, “Artsakh Investment Fund” and “Fund for Rural and Agriculture Support” which have to deal with the development and implementation of modern approaches of assessing and managing the risks more in details must strictly require to apply new methods and tools of investment in investment programs.

In order to develop an effective system of investment risk management in Artsakh it is necessary to establish:

- the peculiarities of the formation and implementation of that system,
- the main methods used in different stages of the process of risk management and peculiarities of their application,
- methodology of investment risk management.

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ԳՅՈՒՂԱՏՆՏԵՍՈՒԹՅԱՆ ՈԼՈՐՏՈՒՄ ՆԵՐԴՐՈՒՄԱՅԻՆ ՌԻՍԿԵՐԻ ԿԱՌԱՎԱՐՄԱՆ ՀԻՄՆԱՀԱՐՑԵՐԸ ԱՐՑԱԽՈՒՄ

Շինդյան Կ.Ն.
Շուշիի տեխնոլոգիական համալսարան

Արցախի տնտեսության, հատկապես նրա առաջատար հատվածի՝ գյուղատնտեսության ոլորտի հետպատերազմյան վերականգնման արդի փուլում մեծ կարևորություն ու նշանակություն է ձեռք բերել ներդրումների ներգրավման հիմնահարցերի ուսումնասիրությունը և դրանց լուծման անհետաձգելի քայլերի նախանշումն ու իրականացումը:

Ներկայիս նոր իրողությունների պայմաններում ԱՀ-ում ներդրումների ներգրավման գործընթացը ենթակա է լրացուցիչ ռիսկերի ազդեցությունների, որոնց հայտնաբերման և արդյունավետ կառավարման նպատակով կարևորվում է գիտականորեն հիմնավորված արդիական մեթոդների ու մոտեցումների մշակման ու կիրառման ապահովման հիմնահարցերի հայտնաբերումը և լուծումը:

Բանալի բառեր. ներդրումային ռիսկ, հայեցակարգ, մեթոդաբանություն, ֆինանսական կորուստներ, անորոշություն, մոդել արդյունավետություն:

ПРОБЛЕМЫ УПРАВЛЕНИЯ ИНВЕСТИЦИОННЫМИ РИСКАМИ В СФЕРЕ СЕЛЬСКОГО ХОЗЯЙСТВА АРЦАХА

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На современном этапе послевоенного восстановления экономики Арцаха, особенно ее ведущей отрасли - сельского хозяйства, изучение вопросов привлечения инвестиций, обозначение и осуществление неотложных шагов по их решению приобрели большое значение.

В условиях нынешних реалий процесс привлечения инвестиций в РА сопряжен с дополнительными рисками, с целью выявления и эффективного управления которыми придается важность выявлению и решению проблем разработки и применения научно обоснованных современных методов и подходов.

Ключевые слова: инвестиционный риск, концепция, методология, финансовые потери, неопределенность, модель, эффективность.

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PROBLEMS OF THE USE OF COINTEGRATION PAIRS FOR PAIRS TRADING

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Abstract

This paper describes a pairs trading strategy using cointegration approach. If cointegrated pairs are thought of as such pairs, whose linear combination is a stationary process, that is, a process with stable statistical properties, then any deviation from these characteristics will be transient. If you know that such a deviation has happened, that is, a departure from the long-term equilibrium, you can forecast the direction of stock price movements and execute lucrative trades accordingly. When the difference between stock prices exceeds the prediction, we must sell the overpriced asset and acquire the undervalued one, then close the deals when the price ratio returns to long-term equilibrium. This is one form of statistical arbitrage trading strategy. During the research, it was discovered that cointegration is dependent on a variety of factors, including the time period under consideration, and that this is not the only issue. When more recent data is given more weight, it is suggested that methods for determining cointegration be developed. The importance of setting the conditions for entering and terminating a transaction, as well as the possibility of "disappearing" cointegration are also noted as issues with employing cointegrated pairings for pair trading.

***Key words**:* pair trading, cointegration, cointegrated pairs, time series.

Introduction

Data mining is a modern method of obtaining and identifying ideas about the functioning of an object. In cases of working with dynamic objects, multidimensional time series serve as a source of information. Analysis of the dynamics of time series and forecasting their evolution are of great importance for managing various processes in social (for example, election campaigns), economic (stock, futures and commodity markets) and sociotechnical systems (for example, social networks) [1].

The use of the mathematical apparatus for the transformation of many economic and social processes makes it possible to identify qualitative relationships between various factors and the surrounding space that generates information. Dynamic analysis of digital information makes it possible to develop and implement models to rationalize the control of individual parameters, taking into account the specifics and properties of the object in question. In particular, intelligent algorithmization makes it possible to rationalize the behavior of subjects in specific periods of time by processing a large amount of data and identifying temporary

elements, for example, in the context of building investment strategies or mathematical processing of the information environment [2,3].

When predicting the state of some object system, we are faced with time series. One of the directions in the development of forecasting methods is based on the search for interdependencies between time series. If there is a linear combination of time series that has the properties of a stationary process, it means that these time series are cointegrated. The issues of forecasting cointegrated time series are covered in a number of sources both in general form [4,5,6] and in relation directly to economic [7,8,9] or technical parameters [10,11,12,13].

Methods

The derivation of a functional dependence is used to anticipate processes (economic, technical, and biological) defined by time series. Changes in the values of time series occur in real life due to a variety of reasons and variables. It is not always possible to construct a multifactorial model of the classical type due to their multiplicity and the difficulty of recognizing relationships with the resulting variable. It is not always possible to construct a multifactorial model of the classical type due to their multiplicity and the difficulty of recognizing relationships with the resulting variable. As a result, when it comes to time series, it's common to believe that internal patterns in the growth of process create the cumulative influence of factors [14].

The time series' value should then be decided by the current time or the values of the indicators that are known at that time. An autoregressive series is one that is dependent on its own past values:

$$\gamma_t = \phi\gamma_{t-1} + \varepsilon_t \quad (1)$$

where the random component ε_t has zero mathematical expectation and stable variance $\varepsilon_t \sim N(0,\sigma^2)$.

When using statistical methods, consistency of mathematical expectation, variance and autocorrelation is a common criterion. The stationary character of process is defined by these conditions. It ensures that an appropriate mathematical model to represent the dynamics of this process is chosen. Many economic processes, however, are non-stationary; yet, if the values of the time series develop gradually over time, the time series can be made stationary by eliminating the trend line. This transformation is called difference-stationary [15] if it results in a stationary series. The series will usually become stationary if you proceed from the original series to its initial differences

$$\Delta\gamma_t = \gamma_t - \gamma_{t-1}$$

$$\Delta\gamma_t = \gamma_t - \gamma_{t-1} = \varepsilon_t \quad (2)$$

Let us go on to the cointegration description, presuming we've decided what we mean by stationary time series and how to make a non-stationary time series stationary.

They are called cointegrated if a linear combination $I(1)$ of time series $Y_t = (y_{1t}, y_{2t} \dots y_{nt})^T$ has the features of a stationary series.

$$\beta^T Y_t = \beta_1 y_{1t} + \beta_2 y_{2t} \dots + \beta_n y_{nt} \sim I(0) \quad (3)$$

If there is at least one such vector β, then the data set is considered to be cointegrated. It is clear that if the original series are non-stationary, then for their linear combination to be stationary, then it must include at least two time series. The use of a large number of time

series in the cointegration relation is complicated by interdependencies between non-stationary time series, which causes the effect of multicollinearity.

It is clear that any cointegration vector is not unique, because:

$$k \cdot \beta^T Y_t = (\beta^*)^T Y_t \sim I \tag{4}$$

Usually, the cointegration relation leads to the expression of the dependence of one time series on others, then the cointegration vector can be written as:

$$\beta = (1, -\beta_2, \dots, \beta_n)^T \tag{5}$$

Thus, the cointegration relation can be represented as:

$$\beta^T Y_t = y_{1t} - \beta_2 y_{2t} - \cdots - \beta_n y_{nt} \sim I(0) \tag{6}$$

or

$$y_{1t} = \beta_2 y_{2t} + \beta_3 y_{3t} + \cdots + \beta_n y_{nt} + u_t \tag{7}$$

where $$u_t = \beta^T Y_t \sim I(0)$$

It turns out that we assume the existence of some kind of long-term equilibrium equation:

$$y_{1t} = \beta_2 y_{2t} + \beta_3 y_{3t} + \cdots + \beta_n y_{nt} \tag{8}$$

The fact that some pairs of financial assets are interrelated or dependent on one set of external factors explains cointegration between financial time series. If the presence of cointegration necessitates the formation of a stationary process by the combining of time series. It goes without saying that if there are many time series, there can be multiple such combinations, hence we refer to a set of cointegrating vectors as follows:

$$B^T Y_t = \begin{pmatrix} \beta_1^T Y_t \\ \vdots \\ \beta_r^T Y_t \end{pmatrix} = \begin{pmatrix} u_{1t} \\ \vdots \\ u_{rt} \end{pmatrix} \sim I \tag{9}$$

The time series dependence model can be described in the form of an error-correction model (ECM) in the situation of cointegration of $I(1)$ series [16]. That is, a functional dependency can be formalized as follows:

$$\Delta y_{1t} = f(y_{1t-1} - (\beta_2 y_{2t-1} + \beta_3 y_{3t-1} + \cdots + \beta_n y_{nt-1})) = f(u_{t-1}) \tag{10}$$

The random component u_t has no mathematical expectation, but the value of the random component in the previous step determines the next change in the time series. As a result, if the processes are cointegrated, they gravitate to the values established by the long-term equilibrium (8). Returning to the financial market, if two stock prices are cointegrated, their price ratio may be violated at different times, but it will eventually return (tend) to a recognized level. You can use this to monitor the value of the random component u_t, and if its analysis shows that this value began to behave differently than a stationary process at some point, you can suspect the occurrence of some changes in the processes, that is, fix a violation of the long-term equilibrium. In technology, this could mean a breakdown, an accident, the need to replace equipment, and so on, and in the economy, it could mean some structural changes. While the procedures for evaluating time series for stationarity and cointegration are

widely documented while methods for anticipating changes in cointegration relationships are not.

Results

The process of identifying cointegration between time series requires mathematical justification. The presence of visual similarity of the series and strong correlation does not guarantee the existence of causal relationships.

Fig. 1 Stock price dynamics and values 60/120/240 daily Values pairwise correlations for BKR and WHD assets

Fig. 2 Stock prices dynamics and values 60/120/240 of daily pairwise correlations for NFLX and AMZN assets from 2018-01-02 to 2021-09-01

There is more similarity between the BKR and WHD stock price charts (Fig. 1) than between the NFLX and AMZN stock price charts (Fig. 2) and the value of the correlation

coefficient is higher in the first pair of stocks, however, the Engle-Granger test shows that there is no causal relationship in the first pair. connections (Fig. 3), and in the second pair there is (Fig. 4).

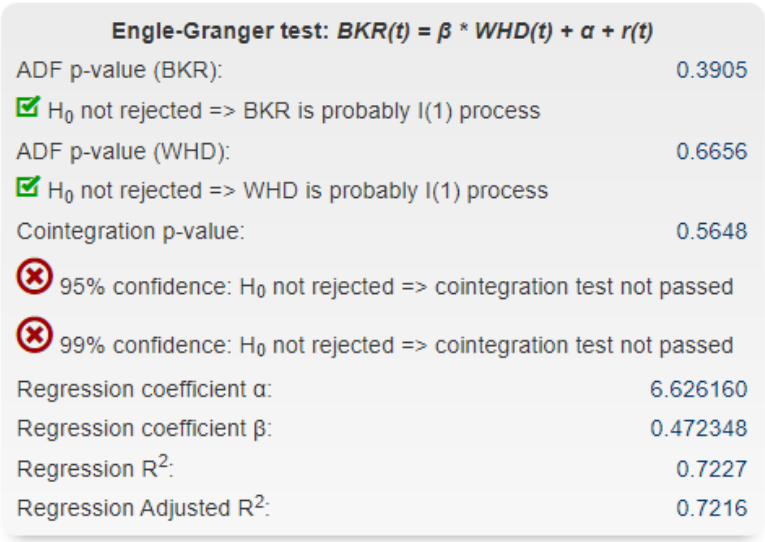

Fig. 3 Engle-Granger test results for BKR and WHD assets

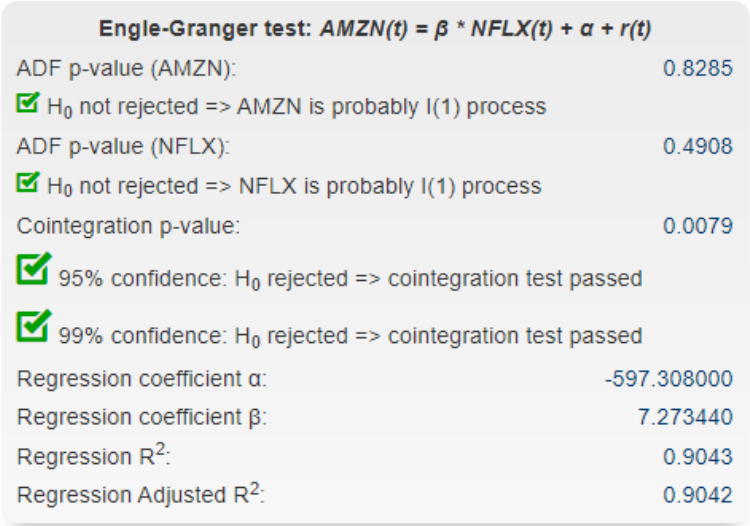

Fig. 4 Engle-Granger test results for assets NFLX and AMZN for the period from: 2018-01-02 to:2021-09-01

Let us look at several cointegration-based trading strategies. Pair trading, or cointegration-based trading, is when trades are conducted with each of the assets in a pair [17]. Private cointegration was utilized by Clegg, M., and Krauss, C. (2018) to select trading pairings and create buy and sell signals. They note that such a trading strategy has good performance indicators. “We compared private cointegration with several classic pair trading options from 1990 to 2015 on a data set for S&P 500 participants. The annual return was more than 12 per cent after operating costs.

These results can only be partly explained by common sources of systematic risk, and are significantly superior to classical distance or cointegration-based pair trading options in our dataset [18].

When a temporal divergence happens, the higher performing stocks (stocks that have increased in value) must be sold, while the lower performing stocks (stocks that have

decreased in value) must be bought at the same time. At the same time, it's important to remember that the spread between the two equities will eventually equalize (8). This will occur either as a consequence of the higher performing stocks falling back, or as a result of the lower performing stocks increasing, or both, resulting in a profit on your transaction. There is no profit or loss if both equities move up or down at the same time without changing the spread between them [19].

The spread value is the $u_t = y_{1t} - (\beta_2 y_{2t} + \beta_3 y_{3t} + \cdots + \beta_n y_{nt})$ from formula (7) in general and in particular in pair trading

$$u_t = y_{1t} - (b_1 + b_2 y_{2t}), \tag{11}$$

where y_{1t}, y_{2t} are share prices of the cointegrated pair, b_1, b_2 are coefficients of the regression equation that determine the relationship between them, then the spread has the properties of a stationary process.

Therefore, trading in pairs can be considered as a market-neutral trading strategy that allows traders to profit in different market conditions: rising and falling markets or sideways. This strategy belongs to the category of statistical arbitrage trading strategies.

If the strategy tracks the relationship between the returns of a pair of market assets, then it remains to consider how stable such a relationship is over time. The essence of the strategy is that they can deviate from some of their long-term equilibrium, but return to it. Therefore, trading in pairs can be viewed as a market-neutral trading strategy that allows traders to profit in different market conditions: rising A divergence within a pair can be caused by temporary changes in supply/demand, large buy/sell orders for one security, a reaction to important news about one of the companies, etc.

Due to market neutrality, this trading strategy can be very safe (provided it is diversified) and immune to a global market crisis, even when the entire market or sector collapses. If you trade enough pairs at the same time, your pairs trading portfolio can perform well in difficult market situations as well.

Indeed, in order for the strategy of trading in concatenated pairs to be profitable, no matter in what direction the market or stock prices within the pair move, the main thing is that the linear combination of a stock pair In cases where the difference between stock prices turns out to be greater than the forecast, we need to sell the overvalued asset and buy the undervalued one, and when the price ratio returns to long-term equilibrium, close the deals. known to us can be described as a stationary process with a stable mathematical expectation.

Consider the situation of losing trades. Losses can occur when the cointegration ratio has changed or the cointegration between rows has disappeared. However, rapid market changes can break the relationship (namely a structural gap), which will further lead to huge losses in intraday trading. [20]. That is, if transactions are made for a pair of assets in some ratio, in the hope that the current deviation (10) from this ratio (9) will eventually become 0 (for example), and ratio (9) has changed under the influence of some factors and is no longer a long-term equilibrium, then these transactions will incur losses. It must be understood that cointegration can appear and disappear. Let's consider specific examples. For example, Fig. 2 and 4 show a pair of stocks of Netflix, Inc. and Amazon.com, Inc. and when analyzing the entire period From:2018-01-02 To:2021-09-01, cointegration is observed. Engle-Granger test indicates the presence of a causal relationship. The same test for the period From: 2018-01-02 To: 2018-12-31 indicates a lack of communication (Fig. 5, 6).

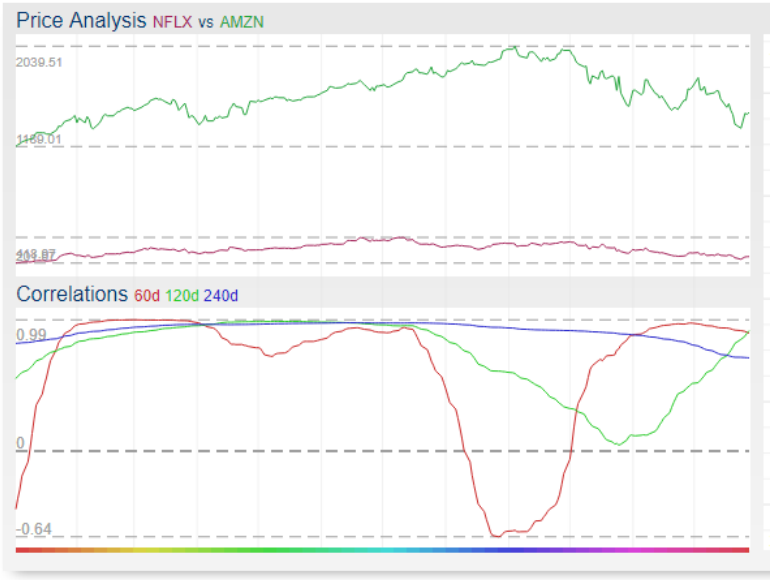

Fig. 5 Stock price dynamics and 60/120/240 daily pair correlations for BKR and WHD assets over the period from 2018-01-02 to 2018-12-31

Engle-Granger test: *AMZN(t) = β * NFLX(t) + α + r(t)*	
ADF p-value (AMZN):	0.2089
☑ H_0 not rejected => AMZN is probably I(1) process	
ADF p-value (NFLX):	0.2243
☑ H_0 not rejected => NFLX is probably I(1) process	
Cointegration p-value:	0.6790
⊗ 95% confidence: H_0 not rejected => cointegration test not passed	
⊗ 99% confidence: H_0 not rejected => cointegration test not passed	
Regression coefficient α:	638.845000
Regression coefficient β:	3.139750
Regression R^2:	0.6089
Regression Adjusted R^2:	0.6074

Fig. 6 Engle-Granger test results for assets NFLX and AMZN for the period from 2018-01-02 to 2018-12-31

The regression equation and the coefficient of determination have also changed.

Conclusion

An analysis of the possibilities of using cointegrated pairs for pair trading showed a number of problems that need to be solved for their successful use.

The first problem associated with determining which period to take for analysis is more general than the problem of analyzing cointegrated pairs. This aspect is important for the analysis of any kind of time series. It seems promising to give more recent data more importance in the analysis, as, for example, is done with exponential smoothing.

Even if we assume that the cointegration ratio is stable, and we believe that it will not change in the future, then the question remains of determining the values of the entry and exit criteria for transactions and whether these criteria will change.

The next objective of the researchers should be to address the fact that the cointegration ratio or the presence of cointegration as a whole can alter (cointegration can “disappear”), and that this process must be anticipated (forecast). As a result, the trader must be given the

conditions by which he can stop considering the pair to be cointegrated and stop using it for pair trading. If we assume that the cointegration ratio is constant and will not change in the future, the question of calculating the values of transaction entry and exit criteria as well as whether these criteria will change or remains.

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ՀԱՄԱԻՆՏԵԳՐՎԱԾ ԶՈՒՅԳԵՐԻ ՕԳՏԱԳՈՐԾՄԱՆ ԽՆԴԻՐՆԵՐԸ ԶՈՒՅԳ ԹՐԵՅԴԻՆԳԻ ՀԱՄԱՐ

Ֆայզուլլին Ռ.Վ.

ՄԻՐԷԱ - ՌԴ տեխնոլոգիական համալսարան

Քննարկվում է զույգ թրեյդինգի համար համաինտեգրված զույգերի օգտագործման հնարավորությունը: Եթե համաինտեգրված զույգերի տակ հասկացվում են այնպիսի զույգեր, որոնց գծային համադրությունը ստացիոնար գործընթաց է, ապա ենթադրվում է, որ այդ բնութագրերից հնարավոր շեղումը ժամանակավոր կլինի: Երբ տեղի է ունենում նման շեղում, հնարավոր է դառնում կանխատեսել բաժնետոմսերի գների փոփոխությունների ուղղությունը և կատարել համապատասխան շահութաբեր գործարքներ: Ուսումնասիրության ընթացքում հաշվի է առնվել, որ համաինտեգրումը կախված է մի շարք պարամետրերից, այդ թվում՝ դիտարկվող ժամանակահատվածից, և դա միակ խնդիրը չէ: Առաջարկվում է մշակել համաինտեգրման հաշվարկման մեթոդներ, երբ առավել թարմ տվյալներին մեծ կշիռ է տրվում: Հետաքրքրություն են ներկայացնում նաև զույգ թրեյդինգի համար համաինտեգրված զույգերի օգտագործման խնդիրները: Կարևորվում է գործարքից մուտքի և ելքի չափանիշների որոշումը:

Բանալի բառեր. զույգ թրեյդինգ, կոինտեգրացիա, կոինտեգրված զույգեր, ժամանակավոր շարքեր:

ПРОБЛЕМЫ ИСПОЛЬЗОВАНИЯ КОИНТЕГРИРОВАННЫХ ПАР ДЛЯ ПАРНОГО ТРЕЙДИНГА

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В статье рассматривается возможность использования коинтегрированных пар для парного трейдинга. Если под коинтегрированными парами понимаются такие пары, линейная комбинация которых представляют собой стационарный процесс, то есть как процесс со стабильными статистическими характеристиками, то подразумевается что возможное отклонение от этих характеристик будет временными. Если знать что произошло такое отклонение, то есть отклонение от долгосрочного равновесия, то возникает возможность спрогнозировать направление изменений цен акций и сделать соответствующие выгодные сделки. В тех случаях, когда разница между ценами акций оказывается больше прогнозной, нам необходимо продать переоцененный актив и купить недооцененный, а когда соотношение цен вернется к долгосрочному равновесию, закрыть сделки. Это один из видов статистических арбитражных торговых стратегий. В ходе исследования рассмотрено что коинтеграция зависит от ряда параметров, в том числе от рассматриваемого периода и это является не единственной проблемой. Возникает рекомендация разработки методов расчета коинтеграции когда более свежим данным придается больший вес. Также в качестве проблем использования коинтегрированных пар для парного трейдинга выделены важность определения критериев входы и выхода из сделки, а также возможность «исчезновения» коинтеграции.

Ключевые слова: парный трейдинг, коинтеграция, коинтегрированные пары, временные ряды.

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DESIGN OF THE CONTROL SYSTEM FOR THE UNMANNED AERIAL VEHICLE BY MATLAB SYSTEM

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Abstract

The necessity of research and evaluation of the influence of rudder and aileron deflection on the UAV performance is substantiated. It is shown that in the absence of a regulator, periodic oscillations of the yaw occur, sometimes reaching several tens of degrees. A washout filter based on a new method has been developed to improve the performance and flight modes of the UAV.

Key words: control system, UAV, linear time-invariant, rudder, aileron, impulse, root locus, washout filter, damping ratio.

Introduction

A distinctive feature of unmanned aerial vehicles (UAV) is the absence of a pilot on board [1]. The flight of the UAV can operate with varying degrees of autonomy: using a remote control device; using the automatic piloting system which functions both on the device itself and on the flight monitoring and control device. Compared to manned aircraft, UAV are designed to carry out missions that pose a significant danger to people, as well as missions that have an unjustified large expenditure of resources to perform primitive actions. Appropriate software can be installed in the UAV to perform various tasks offline, that is, without human intervention.

Initially, UAV were created primarily for military purposes, but with the development of technology, UAV have found their application in civilian areas (patrol and surveillance,

delivery of goods, aerial photography, video filming, agriculture, etc.). Now an important task is to design an accurate microprocessor system for controlling the UAV.

The purpose of this work is to develop a microprocessor control system for motion analysis, improving the characteristics and reliability of the UAV.

Conflict setting

This paper demonstrates the tools for designing a control system by step-by-step describing the design of a yaw damper for an UAV.

Several aerodynamic forces act on an UAV in level flight, which compensate each other: gravity F_g, wing lift F_l, engine thrust force F_t, air resistance force F_d, stabilizer force F_s compensating the longitudinal moment if the points of application of gravity and lift do not match. The forces acting on the UAV are recalculated and reduced to one point, but due to the fact that in reality the points of application of these forces are different, torques are used [1].

Driving torques rotate the UAV around the axes, just as forces displace the plane along the axes. In total, the UAV has 6 degrees of freedom, movement along the coordinates of the X, Y, Z rectangular axes and rotation around the X, Y, Z axes (Fig. 1). In the MATLAB system for UAV modeling, the Structural Frame coordinate system is used. The X axis in this coordinate system is directed against the movement of the model, the Y axis is to the right along the wing, and the Z axis is directed upward along the symmetry axis in the vertical plane. Drag, side, lift - these are the forces that shift the center of gravity of the model along the corresponding axes. Roll, pitch, yaw - are the torques that rotate the model around the corresponding axis passing through the center of gravity.

At a flight speed 1.25 times less than the speed of sound, at an altitude of 4,000 m, the UAV is given by the description in the state space [2]:

$$X = AX + BU, Y = CX + DU$$

$$A = \begin{pmatrix} -0.0643 & -0.8876 & 0.0701 & 0.0324 \\ 0.4860 & -0.2330 & -0.0216 & 0 \\ -2.8900 & 0.3660 & -0.3740 & 0 \\ 0 & 0.0602 & 1.0000 & 0 \end{pmatrix}, \; B = \begin{pmatrix} 0.0618 & 0 \\ -4.6400 & 0.0066 \\ 5.1320 & 0.1210 \\ 0 & 0 \end{pmatrix}$$

$$C = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, \; D = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$$

where $X \in R^4$ - state vector, U,Y - vectors of input and output signals.

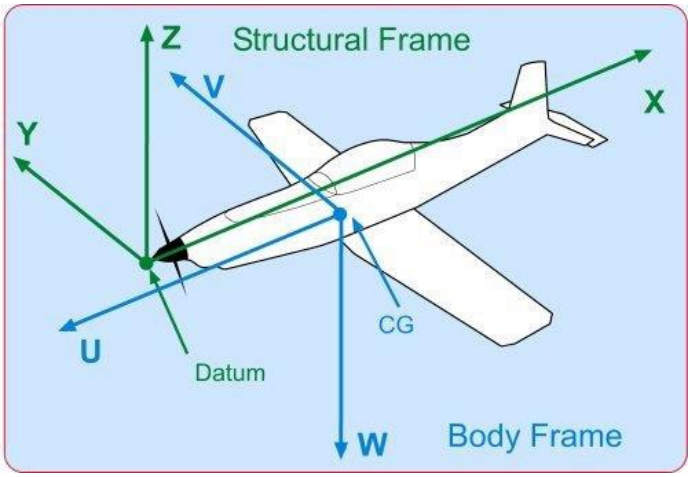

Fig. 1 Coordinate systems and their reference points

The following commands define this state-space model as a linear time-invariant (LTI) system and assign names to the states, inputs, and outputs

```
>> states = {'beta' 'yaw' 'roll' 'phi'};
>> inputs = {'rudder' 'aileron'};
>> outputs = {'yaw' 'bank angle'};
>> sys = ss (A,B,C,D,'statename',states,...
'inputname',inputs,...
'outputname',outputs);
```

The model has two inputs and two outputs. The units are radians for β (side slip angle) and φ (roll angle) and newton per meter for yaw and roll. Rudder and aileron deflections are also given in radians.

Calculation of the eigenvalues of an open system is carried out using the damp function.

```
>> damp(sys)
```

Eigenvalue	Damping	Freq. (rad/s)
-7.28e-003	1.00e+000	7.28e-003
-5.63e-001	1.00e+000	5.63e-001
-3.29e-002 + 9.47e-001i	3.48e-002	9.47e-001
-3.29e-002 - 9.47e-001i	3.48e-002	9.47e-001

The location of zeros and poles in the complex plane can be obtained by typing the *pzmap (sys)* command with no output argument.

This model has one pair of lightly damped poles. They correspond to the so-called “Dutch rolling regime” [1]. It is necessary to design a compensator that increases the damping of these poles so that the resulting complex poles have a damping coefficient ζ>0.35 with a natural frequency $\omega_n < 1$rad/s. This can be done using the analysis tools of the Control System toolbar.

Open system analysis

We shall now derive some open-loop analysis to determine possible control strategies. To simulate the UAV, an impulse function is used, which is the response of the system to the input signal in the form of a delta function [3]. Graphs of the impulse function have been studied, which make it possible to determine the regulation law (Fig. 2). The impulse response confirms that the system is slightly damped.

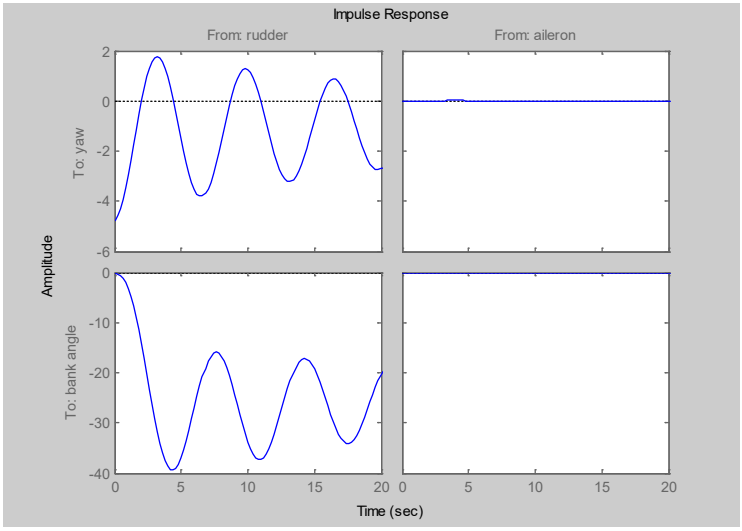

Fig. 2 Graphs of the impulse function for an open system on the interval 0≤t≤20

Of great interest is the graph from aileron deflection (input 2) to bank angle (output 2). To display only this graph, you must right-click and select I/O Selector, then click on entry (2,2). The resulting new graph is shown in Fig. 3.

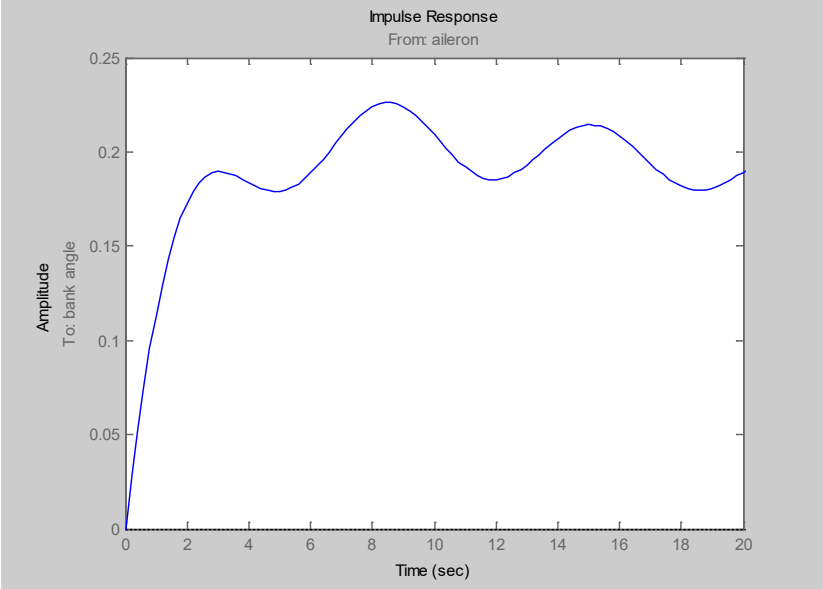

Fig. 3 Graph of the impulse response for an open system from input 2 (aileron deflection) to output 2 (roll angle)

The UAV oscillates around a non-zero bank angle. Thus, the UAV turns in response to the aileron impulse. This behavior will prove to be an important point in the analysis of UAV movement.

The root locus method

The design goal is to provide a damping coefficient ζ>0.35 with natural frequency $\omega_n < 1.0$ rad/s. Since the simplest compensator is the static gain, we first try to determine the appropriate gain values using the root locus method. UAV parameters can be displayed by command:

```
>> rlocus(sys11)
```

This is a root locus with negative feedback, which shows that the system becomes unstable almost immediately [4]. If we use a positive feedback system instead, we can get a stable system with the following command (Fig. 4):

```
>> rlocus(-sys11)
>> sgrid
```

Using simple feedback, a damping coefficient of ζ=0.45 can be achieved. To do this, click on the top curve and move the data marker to track the gain and damping coefficient. To achieve a damping coefficient of 0.45, the gain should be around 2.85. The creation of a closed linear system with the specified gain is carried out by the command:

```
>> K = 2.85;
>> cl11 = feedback (sys11, -K);
```

The output of the graph of the impulse response of a closed system with a given range of values along the abscissa axis and its comparison with the graph of the impulse response of an open system is performed using the function:

>> impulse (sys11,'b--', cl11,'r',20)

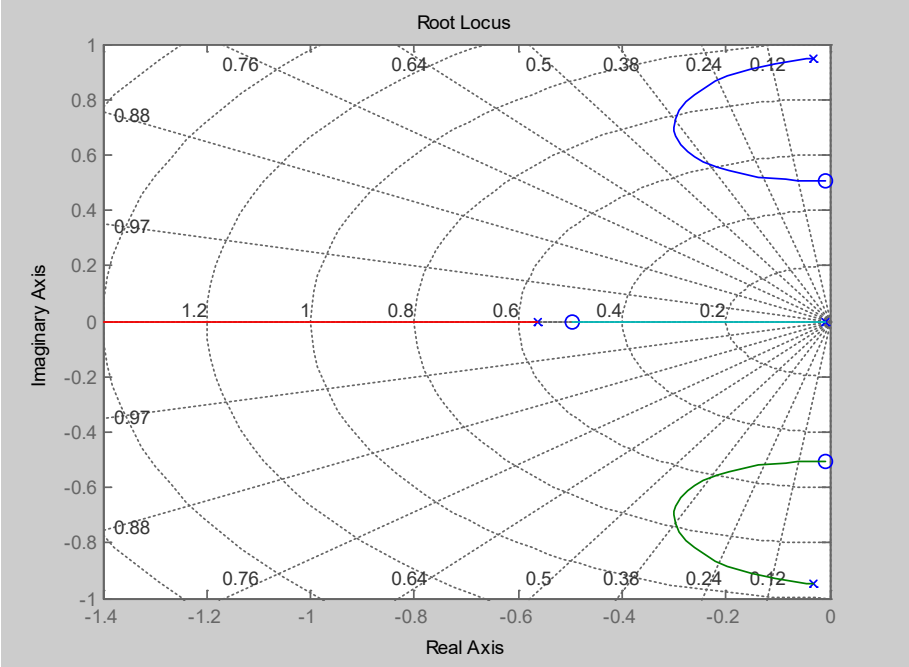

Fig. 4 Root locus of a system with positive feedback

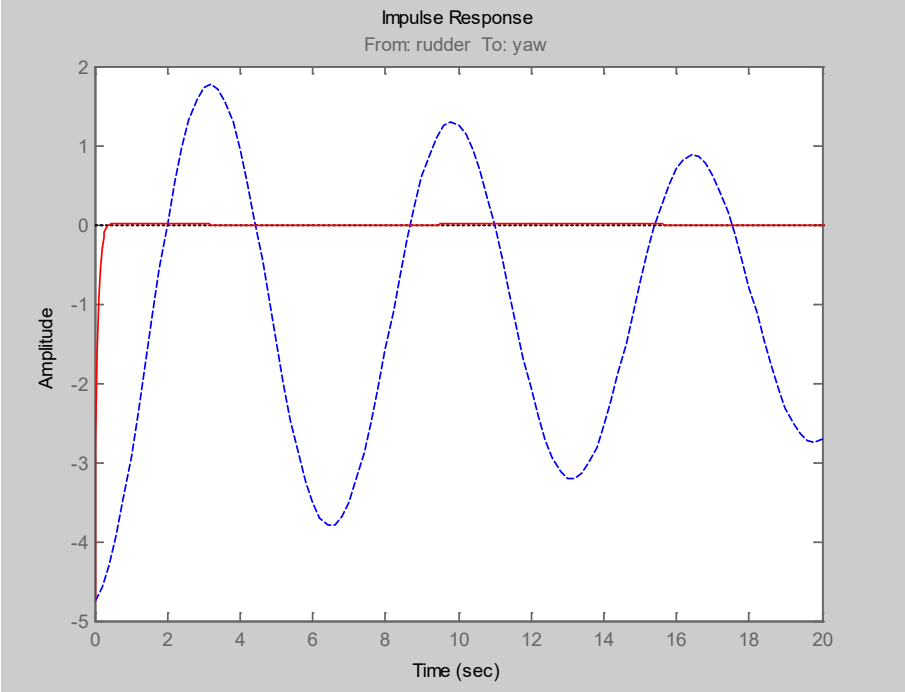

Fig. 5 Comparison of graphs of impulse responses for closed and open systems

The response of a closed-loop system with feedback is established quickly and does not fluctuate much, compared to the response of an open-loop system (Fig. 5).

As can be seen from Fig. 2 this MIMO system with r=2 inputs and m=2 outputs contains 2x2 mappings $u_i \to y_j$, $i = 1, \dots r$, $j = 1, \dots m$. Each mapping of the i-th input to the j-th output can be described by a scalar transfer function $Q_{ij}(p)$. Together they form a 2x2 matrix impulse function Q(p). In a MIMO system, feedback from output 1 to input 1 is considered, and for this case, using the *feedback* and *damp* commands, we obtain:

```
>> cloop = feedback (sys, -K,1,1);
>> damp(cloop)
```

Eigenvalue	Damping	Freq. (rad/s)
-4.89e-001	1.00e+000	4.89e-001
-3.44e-002 + 5.05e-001i	6.80e-002	5.06e-001
-3.44e-002 - 5.05e-001i	6.80e-002	5.06e-001
-1.36e+001	1.00e+000	1.36e+001

On Fig. 6 splitting the current graphic window for displaying comparative graphs of the impulse response of the MIMO system is performed using the function:

```
>> impulse (sys,'b--', cloop,'r',20)
```

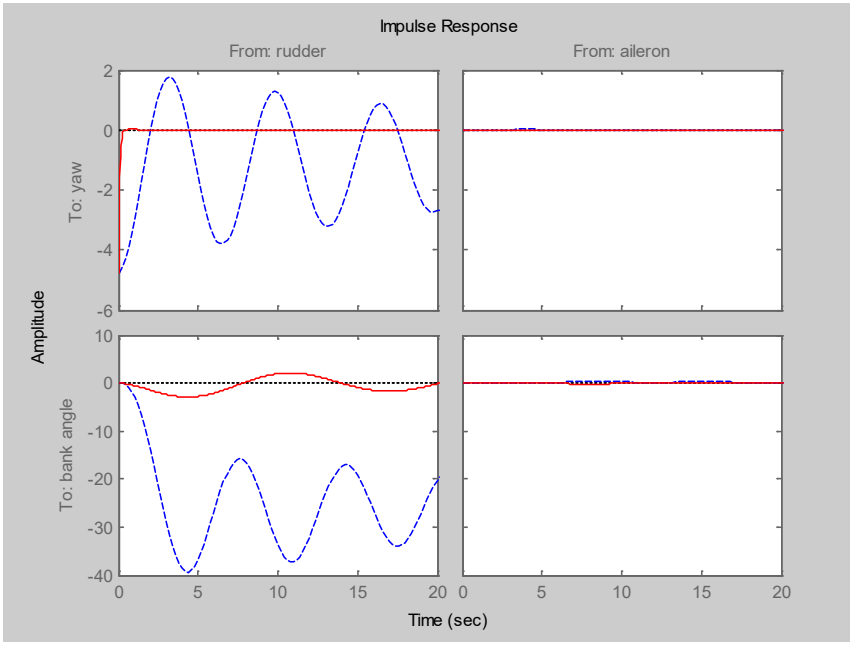

Fig. 6 Comparison of graphs of impulse response for closed and open systems

The yaw response now decays nicely, but look at the graph from ailerons (input 2) to bank angle (output 2). When you move the ailerons, the system no longer continues to bank like a normal UAV. You have over-stabilized the spiral mode. The spiral mode is typically very slow mode and allows the UAV to bank and turn without constant input of the ailerons.

Research results

It must be ensured that the spiral mode does not move further into the left half-plane when a closed system is considered. One way to solve this problem by developers of UAV control systems is to use a washout filter H (s), the transfer function of which has the form

$$H(s) = \frac{s}{s+a}$$

The washout filter places zero at the origin, causing the spiral mode pole to remain near the origin. For the time constant, a value is chosen such that a=0.2 and the root locus technique is used to find the filter gain k. First, using the *zpk* constructor, we write:

>> H = zpk (0, -0.2,1);

By connecting the washout filter in series with the sys11 design model (relationship between input 1 and output 1), the open-loop system can be written as follows:

>> oloop = H * sys11;

and for this open-loop system model, using the root locus method, we obtain (Fig. 7)

>> rlocus(-oloop)

>> sgrid

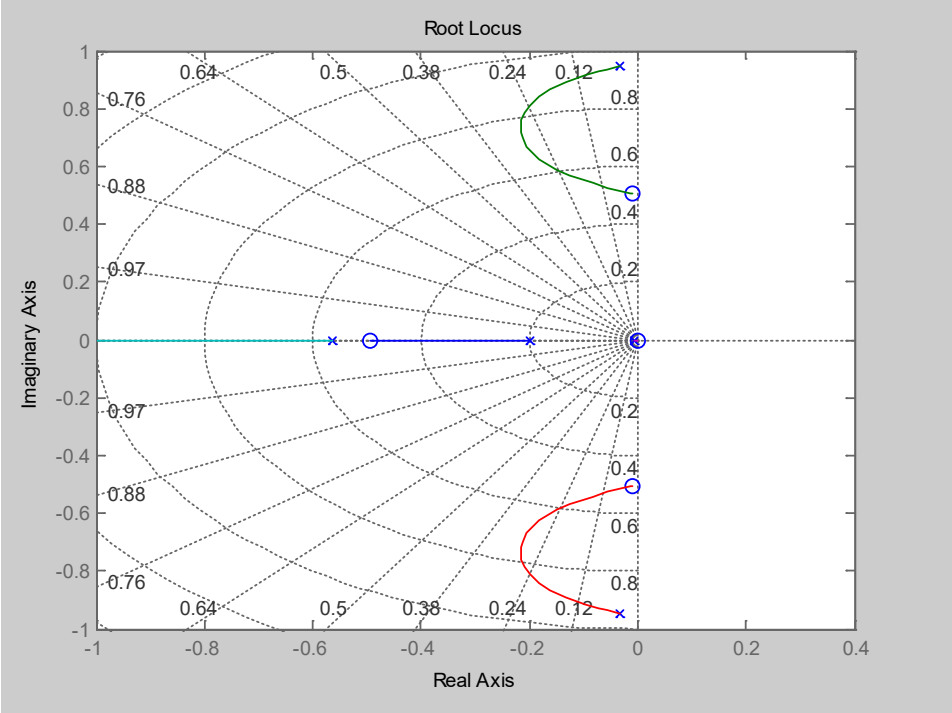

Fig. 7 Root locus of an open system when using a washout filter

By creating and dragging a data marker along the top curve in Fig. 7, the maximum damping can be determined, which is about ζ=0.3.

From Fig. 7, it can be found that at the maximum damping coefficient, the gain is approximately 2.07.

Consider the impulse response for a closed system from input 1 (rudder deflection) to output 1 (torque for yaw)

>> K = 2.07;

>> cl11 = feedback (oloop, -K);

>> impulse(cl11,20)

The calculated graph is shown in Fig. 8.

The response is well stabilized, but has less damping than in the previous case without the flush filter. It can be seen that the use of a washout filter eliminates the spiral mode problem. To do this, it is first necessary to form a complete washout filter kH(s)

>> WOF = -K * H.

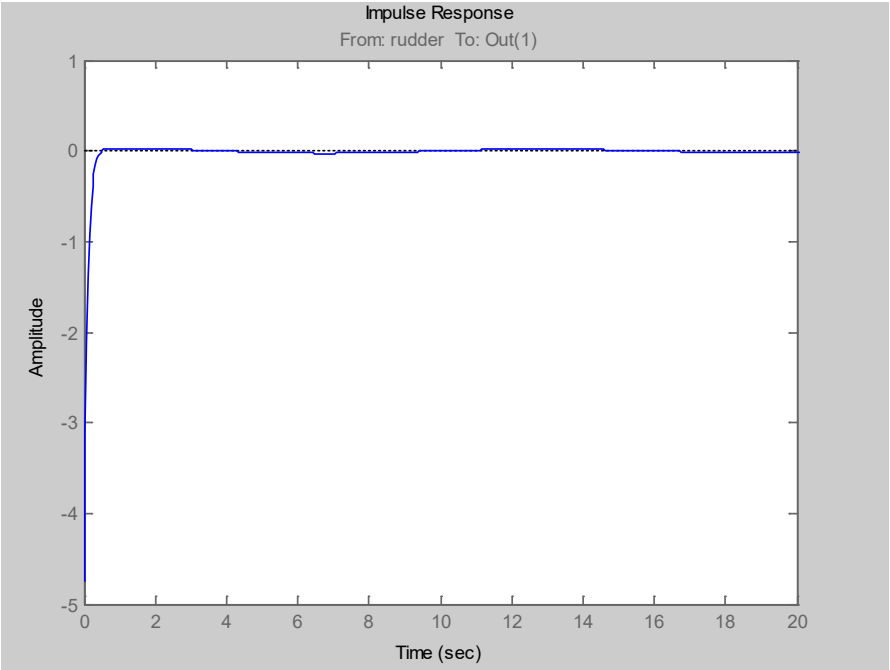

Fig. 8 Graph of the impulse response for a closed system from input 1 to output 1

When modeling MIMO systems sys with feedback from output 1 to input 1, control is given not in the form of a vector, but in the form of a matrix, and we find the system's response to the delta function:

>> cloop = feedback (sys, WOF,1,1);

>> impulse (sys,'b--', cloop,'r',20)

The calculated curves are shown in Fig. 9.

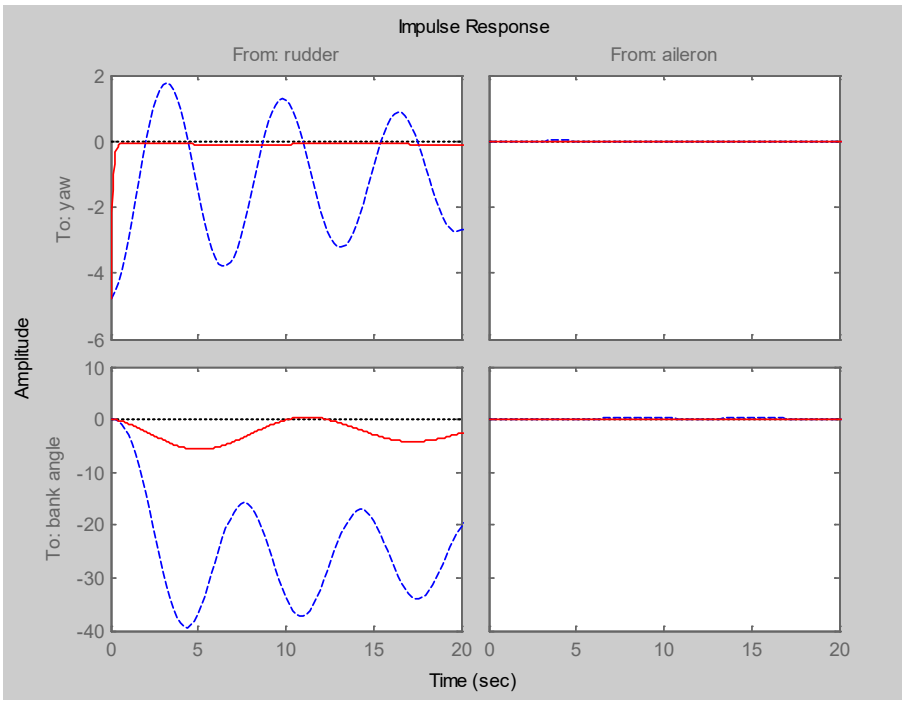

Fig. 9 Comparison of graphs of impulse response for open and closed systems when using a washout filter

The response of the MIMO system at output 2, i.e. the bank angle due to an input 2 aileron pulses is now at the desired, nearly constant value for this short period of time. For a

more detailed study of the curve of dependence of the angle of bank on the aileron, the input-output selector in the menu called by the right mouse button (Fig. 10) is used.

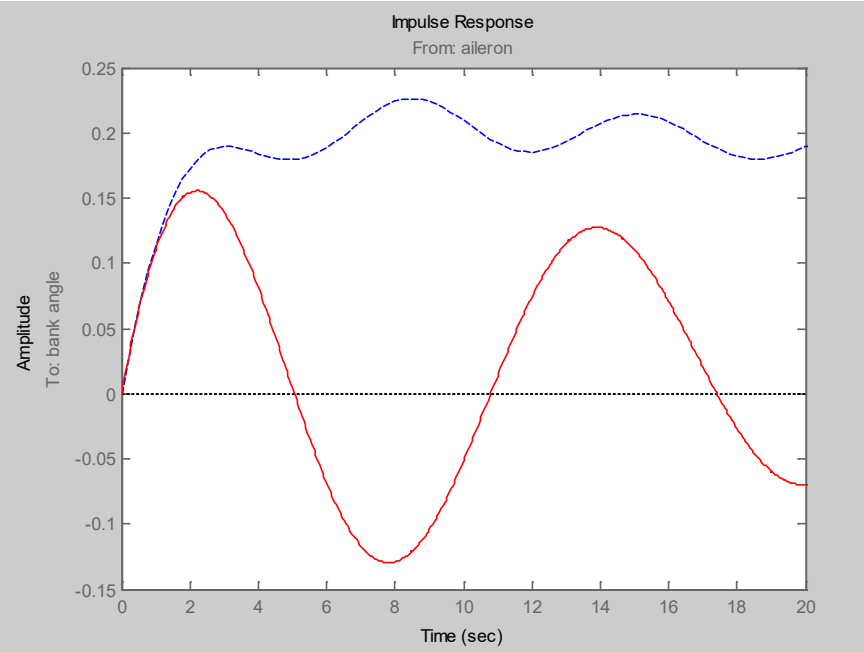

Fig. 10 Comparison of graphs of impulse response for open and closed systems in the case of an input-output pair = (2,2)

From Fig. 10 shows that for the developed design, the damping coefficient has increased significantly and now the controller controls the UAV in the normal mode.

Conclusion

The impulse response for the UAV yaw angle is shown in Fig. 5. Note that the yaw torque settling time is 0.1 s, which is much less than the settling time for an unregulated UAV (i.e., for an open loop system). We also note the complete absence of high-frequency oscillations in the impulse response for the yaw torque and the stationary error is zero. But for a simple controller, the UAV no longer continues to bank when the aileron deflection changes. Therefore, to eliminate the spiral mode, a washout filter is used as a regulator. In this case, the yaw torque response is well stabilized and the problem of spiral mode is eliminated at the same time. Thus, with the use of the washout filter, the impulse response of the UAV has improved significantly.

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MATLAB ՀԱՄԱԿԱՐԳԻ ՄԻՋՈՑՈՎ ԱՆՕԴԱՉՈՒ ԹՌՉՈՂ ԱՊԱՐԱՏԻ ԿԱՌԱՎԱՐՄԱՆ ՀԱՄԱԿԱՐԳԻ ՆԱԽԱԳԾՈՒՄ

Կիրակոսյան Գ.Հ., Մելքոնյան Վ.Ս., Ավետիսյան Ք.Ա.
Հայաստանի ազգային պոլիտեխնիկական համալսարան

Հիմնավորված է անօդաչու թռչող ապարատի աշխատանքային բնութագրերի վրա ուղղության ղեկի և էլերոնի շեղման ազդեցության հետազոտման և գնահատման անհրաժեշտությունը: Ցույց է տրված, որ կարգավորիչի բացակայության դեպքում տեղի է ունենում ընթացաշեղման անկյան պարբերական տատանումներ, որոնք երբեմն հասնում են մի քանի տասնյակ աստիճանի: Նոր մեթոդի վրա հիմնված լվացման ֆիլտր է մշակվել՝ բարելավելու ԱԹԱ-ի աշխատանքային բնութագրերը և թռիչքի ռեժիմները:

Բանալի բառեր. կառավարման համակարգ, անօդաչու թռչող ապարատ, գծային ստացիոնար դինամիկ համակարգ, ուղղության ղեկ, էլերոն, իմպուլսային կշռային ֆունկցիա, արմատային հոդոգրաֆ, լվացման ֆիլտր, հանդարտեցման գործակից:

ПРОЕКТИРОВАНИЕ СИСТЕМЫ УПРАВЛЕНИЯ БЕСПИЛОТНЫМ ЛЕТАТЕЛЬНЫМ АППАРАТОМ С ПОМОЩЬЮ СИСТЕМЫ MATLAB

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Обоснована необходимость исследования и оценки влияния отклонения руля направления и элерона на рабочие характеристики БПЛА. Показано, что при отсутствии регулятора имеют место периодические колебания угла рысканья, достигающие иногда нескольких десятков градусов. Разработан промывочный фильтр на основе нового метода для улучшения рабочих характеристик и режимов полета БПЛА.

Ключевые слова: система управления, беспилотный летательный аппарат, линейная стационарная динамическая система, руль направления, элерон, импульсная весовая функция, корневой годограф, промывочный фильтр, коэффициент демпфирования.

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IMPACT OF METHODS OF SOIL CULTIVATION AND TIMING OF FERTILIZATION ON INCREASING THE DROUGHT RESISTANCE OF WINTER WHEAT IN NATURAL CONDITIONS

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Abstract

In order to mitigate the decline and loss of crop yields due to the deterioration of ecological conditions, the impact of methods of soil tillage and fertilization on regulation of water regime and increase of drought resistance of winter wheat was studied in the brown gravel soils of the lowland zone of Martuni region in the conditions of rainfed agriculture.

The advantage of the zero tillage over the improvement of water properties of soil compared to the traditional tillage was revealed by experimental-research method and also the positive effect of phosphorus-potassium fertilizers and the negative impact of nitrogen and complete fertilizers used before tillage on such physiological property which provides drought tolerance of wheat plants as the decrease of intensity of transpiration was found out. At the same time, it turned out that phosphorus-potassium fertilizers given before sowing and nitrogen fertilizer given in the spring as nutrient create a equal balance of nutrients in plants,

xerophyte traits are developed in plants and high crop yield is obtained in the conditions of high tension of atmospheric factors.

Key words: tillage with furrow turn, zero tillage, field humidity, fertilizing period, transpiration intensity, whaet yield.

Introduction

Edward Faulkner, the founder of US Rehabilitation Agriculture, expressed an idea about the water regime of the soil, that the water regimes in the cultivated and uncultivated lands are completely different. According to Faulkner, the surface of uncultivated soils is covered with a protective layer of plant debris and linear connection from underground water to soil surface is provided, but in cultivated lands tillage interrupts this connection and soil simply stops working until irrigation is renovated. The top layer of untreated soil, rich in organic matter, involves many factors contributing to plant growth in the soil process. It accumulates and retains several times more water in its entire volume than the clay-sand particles that make up the inorganic part of the soil which retain water only on their surface. In addition, the top layer collects and retains groundwater, which allows plants to withstand even prolonged drought. The topsoil moisture not only satisfies the need of plants for water but also promotes the decomposition of organic matter. Thus, the water in the soil is enriched with secondary nutrients, and the water in the subsoil absorbed by the same soil enriches it with primary elements [1].

The founder of Russian agriculture I.E. Ovinsky emphasized the concept of atmospheric irrigation in regulating the water regime of the soil, according to which the soil can condense a significant amount of air moisture, a large amount of gases and dust due to differences in the temperature of the deep layers of the soil and atmosphere. According to Ovinsky, the first condition for atmospheric irrigation should be the porosity of the soil, that is, all its naturally formed pores and holes should be preserved, second, the soil temperature should be lower than air temperature, and third, the soil moisture should be preserved at great depths, this moisture can only be effective when rising through undamaged vessels to warmer upper layers of the soil creating favorable conditions for the growth of bacteria living there which fix free nitrogen in the atmosphere. According to this statement, deep tillage is twice harmful. First, it leaves bacteria there where they can not live, and on the other hand, it destroys the natural porosity of soils, which inhibits both atmospheric irrigation and the activity of nitrifying and nitrogen-fixing bacteria. And 5 cm deep surface loosening is a good guarantee for nitrification and atmospheric irrigation, because in such cultivation the soil is constantly subject to ventilation, its temperature in the lower layers is always so low that atmospheric irrigation takes place very actively, the soil retains its capillary system as a result of which the moisture rises to the upper warm layers promoting the vital active activity of nitrifying bacteria and seed germination [2].

As a result of the research carried out in the conditions of the irregular wetting zone of Stavropol region (2015), L.A. Petrova and others came to the conclusion that the moisture used by plants for crop yield, is better accumulated and stored in the zero crop cultivation system than in the case of sowing with traditional technology [3].

According to the researchers, cultivation from the driest steppes to the non black soil zone improves the water supply of crops and prevents soil drought which is due to the continuous wing tillage that causes agrophysical degradation of the soil [4, 5, 6].

An important agronomic measure to fight drought is the correct definition of the time of the inserting of various mineral fertilizers into the soil.

The role of fertilizers in the fight for high yields of crops has long been known. However, the problem of reducing the destructive effects of external adverse factors with the help of fertilizers was mentioned only in the second half of the 19th century.

K.A. Timiryazev pointed out that among the external influences with which a person can reduce the inefficient consumption of water by plants, he first of all refers to the use of fertilizers in his famous lecture "Plant Fight against Drought" in 1882 [7].

Due to the increase in the amount of colloidal water and the increase in plasma viscosity, phosphorus increases the water retention capacity of the protoplasm.

The positive effect of potassium on the water regime and drought resistance of wheat plants is emphasized in the work of a number of researchers.

Many researchers believe that potassium increases the water retention capacity of plasma colloids, reduces transpiration and increases the amount of water. Nitrogen fertilizers applied to the soil before sowing promote the development of mesophytic properties in plants, which significantly reduces their resistance to unfavorable external conditions [8, 9, 10].

Conflict setting

In a zone of insufficient moisture such as our republic, the problem of regulating the water regime of sowing is the accumulation, storage and effective use of soil moisture. In such conditions, the problems of protection of soil moisture and drought control should be solved together with the fight against wind and water erosion in one complex using soil protection agro-technologies, special equipment for its implementation, reclamation, forest reclamation and other measures giving special place to recently widely adopted free, minimal tand zero soil cultivation.

Based on the above mentioned, we have set a task to find out the impact of mineral fertilizer and time of its introduction dates, the main methods of soil cultivation, effective accumulation of soil moisture, its storage, increase of plant drought resistance and finally increase of crop yield of winter wheat through experimental research.

Material and method

Researches have been carried out in two stages: a. field experiments and b. laboratory studies in 2018-2020 at the Chair of Agronomy of Shushi University of Technology.Field experiments were conducted in lowland soils of Martuni region in brown, sometimes limed, gravel and medium strong soils with three repetitions. The total surface of rows comprised 120m^2 and calculated one was 100 m^2. We used the "Krasnodarskaya99" sort of wheat for studies. The following variants were studied:

1. Traditional tillage without fertilizing (testing)
2. $P_{90}K_{60}$ before tillage
3. N_{90} before tillage
4. $P_{90}K_{60}N_{90}$ before tillage
5. $P_{90}K_{60}$ before tillage, N_{90} in spring
6. Mimimal tillage without fertilizing
7. $P_{90}K_{60}$ before tillage
8. N_{90} before tillage

9. $P_{90}K_{60}N_{90}$ before tillage
10. $P_{90}K_{60}$ before tillage, N_{90} in spring as nutrient

In all the years of the research the winter crop was the previous one. The soil is traditionally prepared for sowing according to the agricultural techniques used in the region. After the previous harvest, the stubble was cut with a BDN disk rake (3-5 cm). 3-4 weeks later the field was plowed with PN -4-35 plow of 22-25 cm. The soil was prepared for the minimal sowing in the same time. After surface tillage of the stubble surface tillage of the soil was performed with a (8-10 cm) АБД4х2ПГ disk plow instead of tillage of furrow turn. The fertilizers, according to the experimental scheme, were introduced into the soil during the main cultivation. Nitrogen feeding was done in early spring. Double superphosphate was used as phosphate fertilizer, potassium chloride was used as potassium fertilizer and ammonia nitrate was used as nitrogen. Pre-sowing cultivation and sowing were carried out in mid-November with a КПС-4Г fallow cultivator and СЗУ-3,6 rowing.

Moving nutrients were identified in the 0-15 cm layer of soil before experimenting each year. According to the data obtained, in all the years of experimentation, before fertilizing the soil, the soil of the experimental site was well supplied with only potassium and nitrogen and weakly supplied with phosphorus. Plants were counted during the vegetation period to study field germination, winter resistance, general and effective bushing. Phenological observations and biometric measurements were made during the vegetation. Field soil moisture at different stages of plant development was determined by gravimetric method and transpiration intensity was determined by Ivanov gravimetric method [1]. The grain yield was determined by the method of harvesting and weighing the yield of each variety and replication with a combine. Yield data were subjected to mathematical processing by dispersion analysis.

Reaearch results

The data of dynamics of the change of moisture amount in tillage layer depending on the method of cultivation and time of fertilization are given in Table 1.

Table 1

The data of dynamics of the change of moisture amount in tillage layer (%) depending on the method of cultivation and time of fertilization (average for 2018-2020)

N	Variants	Before sowing	Bushing, tubing	Stalking	Ripening	Before harvesting	Average
1	Traditional tilliage without fertilization (T)	21,35	25,6	25,81	23,64	18,3	22,94
2	$P_{90}K_{60}$	21,42	25,62	26,14	24,19	19,49	23,37
3	N_{90}	21,79	25,71	25,14	23,11	18	22,75
4	$P_{90}K_{60}$ N_{90}	21,34	25,82	25,93	23,94	18,7	23,14
5	$P_{90}K_{60} + N_{90}$	21,4	26,12	26,17	24,23	18,94	23,37
6	Minimal tillage without fertilizing (T)	22,49	27,34	28,12	27,14	20,41	25,10
7	$P_{90}K_{60}$	22,68	28,15	28,62	28,21	22,14	25,96
8	N_{90}	22,74	26,56	27,03	26,45	20	24,55
9	$P_{90}K_{60}$ N_{90}	22,81	27,92	27,45	27,63	21,33	25,42
10	$P_{90}K_{60} + N_{90}$	22,4	28,31	27,74	28,09	22,65	25,83

According to the data obtained, the moisture content of the arable layer depends on both the method of soil cultivation and the timing of application of soil fertilizer. Most of the moisture in the topsoil was accumulated during the minimum tillage options. However, according to the data in the same table, the timing of application of fertilizers into the soil had a significant impact on the accumulation and storage of moisture. If in the case of phosphorus-potassium fertilizers applied to the soil before the minimum tillage and sowing the moisture accumulated in the arable layer was 25.96%, then in the versions with only nitrogen or complete NPK fertilizers before sowing on the same background, the same index was 24, 55 and 25.42% respectively. On the other hand, 25.83% of water in average was accumulated in the arable land in the version fed with nitrogen fertilizer in the spring and with only phosphorus-potassium before sowing.The same pattern has been observed in traditional tillage options.

It can be seen from Table 2 that the wet-dry weights of the first level leaves of the plants calculated from the spike, increase under the influence of fertilizers compared to the controller. The plants with the highest wet weight were those that received phosphorus-potassium fertilizers before sowing, and nitrogen fertilized were those that received it as nutrient in spring.

The total water content decreased to some extent only in those leaves of the plants of type 2 which received phosphorus-potassium fertilizer before sowing compared to the tester, while in other varieties, especially in those where nitrogen fertilizer was applied separately or in combination with phosphorus-potassium fertilizer in autumn before sowing, it increased.The results of the transpiration study show that, in addition to option 2, fertilizers have increased the intensity of transpiration. This can be partially explained by the fact that the total amount of water in plants with a mesophytic structure of leaves increases compared to other variants.

Table 2

The impact of fertilization time and methods of soil tillage on some properties of water regime of laves of winter wheat (average for 2018-2020)

N	Variants	Weight of 10 leaves (g)		Water amount (%)		Intensity of transpiration
		Wet	Dry	According to wet mass	According to dry mass	
1	Traditional tilliage without fertilization (T)	3,842	1,324	65,54	190,18	1,651
2	$P_{90}K_{60}$	3,867	1,39	64,05	178,2	1,468
3	N_{90}	4,891	1,261	74,21	287,81	2,084
4	$P_{90}K_{60}N_{90}$	4,926	1,427	71,03	245,18	1,892
5	$P_{90}K_{60} + N_{90}$	4,993	1,694	66,07	194,71	1,554
6	Minimal tillage without fertilizing (T)	2,956	1,183	59,98	149,87	2,126
7	$P_{90}K_{60}$	3,712	1,491	59,83	148,93	2,052
8	N_{90}	7,125	2,601	63,49	173,93	2,372
9	$P_{90}K_{60}N_{90}$	4,634	1,661	64,14	178,85	2,373
10	$P_{90}K_{60} + N_{90}$	5,126	1,987	61,23	157,96	2,149

Soil cultivation methods and targeted use of mineral fertilizers play an important role in the complex of other measures to achieve a high and stable yield of winter crops.

The definition of optimal fertilization dates not only ensures a stable growth of the crop, but also contributes to the improvement of the quality of the produced products.

This is evidenced by the winter wheat grain yield and crop quality data we received which are presented in Table 3.

Table 3

Yield of winter wheat and the amount of gluten in a grain depending on the methods of soil cultivation and fertilization time

Variants	Crop yield, c/hectare	Supplementing to tester		Gluten outcome c/hectare	Supplementing to tester	
		c/hectare	%		c/hectare	%
Background – traditional tillage without fertilizing (T)	18,7	-	100	3,92	-	100
$P_{90}K_{60}$	19,9	1,2	6,4	4,17	0,25	6,37
N_{90}	20,3	1,6	8,5	4,46	0,54	13,77
$P_{90}K_{60}N_{90}$	25,8	7,1	37,9	5,80	1,88	47,95
$P_{90}K_{60} + N_{90}$	28,3	9,6	51,3	6,50	2,58	65,81
Background – minimal tillage without fertilizing (T)	22,6	-	100	4,70	-	100
$P_{90}K_{60}$	25,1	2,5	11,0	5,15	0,45	9,57
N_{90}	26,7	4,1	18,3	5,76	1,06	22,55
$P_{90}K_{60}N_{90}$	33,4	10,8	47,7	7,48	2,78	59,14
$P_{90}K_{60} + N_{90}$	35,8	13,2	58,4	8,20	3,50	74,46

According to the data, the yield was high, especially in the background of minimal tillage, which is associated with the accumulation of moisture in the soil and its effective use. The impact of dates of fertilizer application on both the quantity and quality of the crop is obvious.

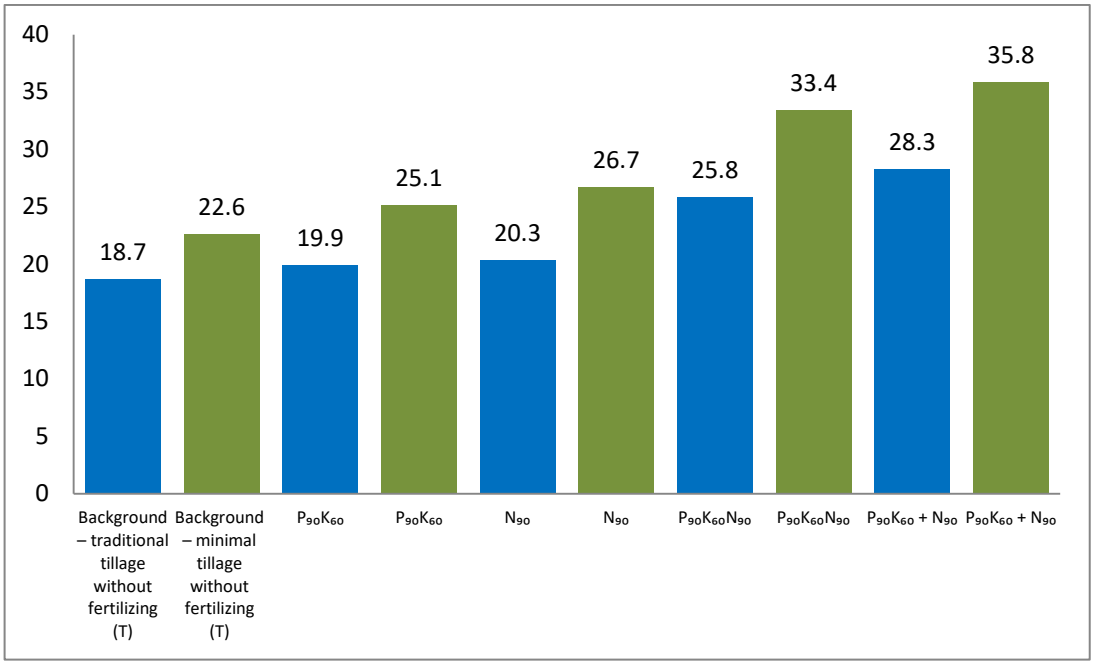

Fig. 1 Yield of winter wheat depending on the methods of soil cultivation and fertilization time

Conclusion

In the conditions of rainfed agriculture in the lowland zone of the Artsakh Republic, where the yield of crops depends mainly on the general tension of the environment and the applied agro-technical measures should be aimed at the effective use of atmospheric moisture. In order to increase the drought resistance of plants and to use moisture economically, it is necessary to define the best dates for the application of mineral fertilizers.

Numerous studies have shown that nitrogen and complete fertilizers dominated by free-nitrogen applied into the soil before tillage, promote the development of mesophytic traits in plants while phosphorus-potassium fertilizers, on the contrary, create the conditions for xerophytic traits.

Plants of high-yielding and resistant to high environmental tension are grown when phosphorus-potassium fertilizers are applied to the soil before sowing and nitrogen fertilizers are applied in spring as nutrients.

On the other hand, in the conditions of minimal soil cultivation, the differentiation of the arable layer according to fertility and the concentration of fertility elements in the top 0-15 cm layer of soil has a significant impact on plant growth and development. Seeds sown in the biologically active layer germinate simultaneously, their field germination is high, the initial growth of plants is accelerated, the transition stages of development are shortened, the energy of bushing is high, winter crops are well matured during winter, they withstand unfavorable conditions of winter well and yield qualified crops at low cost.

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ԲՆԱԿԱՆ ՊԱՅՄԱՆՆԵՐՈՒՄ ՀՈՂԻ ՄՇԱԿՄԱՆ ԵՂԱՆԱԿՆԵՐԻ ԵՎ ՊԱՐԱՐՏԱՑՄԱՆ ԺԱՄԿԵՏՆԵՐԻ ԱԶԴԵՑՈՒԹՅՈՒՆԸ ԱՇՆԱՆԱՑԱՆ ՑՈՐԵՆԻ ԵՐԱՇՏԱԴԻՄԱՑԿՈՒՆՈՒԹՅԱՆ ԲԱՐՁՐԱՑՄԱՆ ՎՐԱ

Գալստյան Ս.Բ., Առաքելյան Ա.Ա., Աթալյան Ս.Լ., Մինասյան Հ.Վ.
Շուշիի տեխնոլոգիական համալսարան

Էկոլոգիական պայմանների բարդացման հետևանքով մշակաբույսերի բերքատվության անկումն ու կորուստը մեղմելու նպատակով Մարտունու շրջանի հարթավայրային գոտու շագանակագույն խճաքարային հողերում, անջրդի երկրագործության պայմաններում, առաջին անգամ հետազոտվել է հողի հինմական մշակման եղանակների և պարարտացման ժամկետների ազդեցությունը հողի ջրային ռեժիմի կարգավորման և աշնանացան ցորենի երաշտադիմացկունության բարձրացման վրա:

Փորձարարա-հետազոտական ճանապարհով բացահայտվել է ավանդական վարի համեմատությամբ հողի մշակման նվազագույն եղանակի առավելությունը հողի ջրային հատկությունների բարելավման վրա, ինչպես նաև պարզվել է ցանքից առաջ հող մտցված ֆոսֆորակալիումական պարարտանյութերի դրական և ազոտական ու լրիվ պարարտանյութերի բացասական ազդեցությունը ցորենի բույսերի մոտ երաշտադիմացկունություն ապահովող այնպիսի ֆիզիոլոգիական հատկանիշի վրա, ինչպիսին տրանսպիրացիայի ինտենսիվության նվազեցումն է: Միաժամանակ պարզվել է, որ ֆոսֆորակալիումական պարարտանյութերը ցանքից առաջ, իսկ ազոտականը սնուցման ձևով գարնանը հող մտցնելիս ստեղծվում է սննդատարրերի հավասարակշռված բալանսավորում, բույսերի մոտ ապահովվում է քսերոֆիտ հատկանիշների զարգացում և մթնոլորտային գործոնների բարձր լարվածության պայմաններում ստացվում է բարձր բերք:

Բանալի բառեր. առի շրջմամբ հերկ, նվազագույն մշակում, դաշտային խոնավություն, պարարտացման ժամկետ, տրանսպիրացիայի ինտենսիվություն, ցորենի բերքատվություն:

ВЛИЯНИЕ СПОСОБОВ ОБРАБОТКИ ПОЧВЫ И СРОКОВ ВНЕСЕНИЯ УДОБРЕНИЙ НА ПОВЫШЕНИЕ ЗАСУХОУСТОЙЧИВОСТИ ОЗИМОЙ ПШЕНИЦЫ В ЕСТЕСТВЕННЫХ УСЛОВИЯХ

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В целях снижения потерь урожая сельскохозяйственных культур в связи с ухудшением экологической обстановки, на коричневых щебнистых почвах равнинной зоны Мартунинского района, впервые было исследовано влияние способов основной обработки почвы и сроков внесения удобрений на регулирование водного режима почвы и повышение засухоустойчивости озимой пшеницы в условиях богарного земледелия.

Экспериментально-исследовательским путем было выявлено преимущество минимального способа обработки почвы на улучшение водных свойств почвы, по сравнению с традиционной вспашкой, а также установлено положительное влияние фосфорно-калийных удобрений, внесенных в почву перед посевом, и отрицательное влияние азотных и полных удобрений на такой физиологический признак, как снижение интенсивности транспирации, обеспечивающей засухоустойчивость зерновых культур. Было также установлено, что фосфорно-калийные удобрения, внесенные в почву весной, перед посевом, а азотные удобрения - в виде подкормки, создают баланс питательных элементов, повышается засухоустойчивость растений и в условиях высокого напряжения атмосферных факторов увеличивается их урожайность.

Ключевые слова: оборотный плуг, минимальная обработка, полевая влажность, сроки внесения удобрений, интенсивность транспирации, урожайность пшеницы.

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COMPUTATIONAL MODELLING OF INFECTIOUS DISEASES AND FORECASTING THEIR SPREAD ON BIG CITIES

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Abstract

COVID-19 pandemic is a global crisis of an unprecedented global scale. Governments were faced with the challenge of designing and implementing policies with great uncertainties concerning their direct impacts and externalities. The effects of so called “policies” were often negative and in some cases further exacerbated the compounding healthcare and economic crises.

This paper presents how computer simulations can be used to test various policies in Yerevan, Armenia, before applying them in real life. Further, it is demonstrated how to identify the features that need to be collected to train well-performing and ethical AI models for healthcare management. Additionally, a machine learning model is introduced that helps to reduce the number of necessary PCR tests by around 98.7%.

Key words**:** covid-19, simulation, machine learning, disease modeling, strategic management, agent-based modeling, healthcare management.

Introduction

The COVID-19 pandemic has had a formative impact on the daily lives of people around the world since December 2019 at such a scale and velocity that is arguably unprecedented in modern history [1]. Numerous lockdowns were implemented by the governments to combat the spread of the virus since then [2]. Approaches to control the pandemic varied from country to country, and although some measures were successful in reducing the speed with which the virus spread, they also had a negative impact on economies, often resulting in recessions [3]. Hence there is a trade-off between the health risks posed by COVID-19 and the economic restrictions resulting from lockdowns and other limitations on economic activity. Therefore, it is important to determine the optimal policies that will minimize the death toll while maximizing economic activity.

Interest in agent-based simulations increased dramatically since the start of the pandemic, primarily because of the freedom and flexibility that they provide. In some cases, models for other infections were re-purposed for COVID-19, in other cases models were developed from scratch [4, 5]. In TU Berlin the MATSim transport mobility simulator was extended to also model the infection spread [6]. While MATSim uses spatial information from real cities for modeling, we opted for an approach that is less computationally complex, more scalable and more "tweakable". The Covasim [7] simulator was developed from scratch to be fast and highly customizable. Covasim uses contact networks for virus transmission. While Covasim is much easier to use, more customizable and can use real-world demographic information, it doesn't take into account the spatial information of real cities. This means that while it is possible to generate simulations for abstract cities, it is not possible to adapt the simulations for specific real-world cities.

Conflict setting

In this paper, we introduce the Evid open-source and agent-based epidemic simulator written in Python. The simulator leverages spatial and demographic information of real cities while ensuring customizability and ease of use. The simulator allows us to model various types of government interventions aimed at reducing the likelihood of a healthcare system becoming overloaded beyond its capacity. We use the number of occupied ICU beds as a metric for healthcare system capacity and usage. The simulator outputs high-level statistics, as well as more granular information. The most granular outcome of the simulator is made similar to the contact tracing methods used by governments.

In the following sections, we demonstrate the structure and logic of the simulator and present an example of the data that it produces. We run the simulator in Armenia's capital city Yerevan with different policy scenarios and show how it can be used by governments for policy testing. We then demonstrate how Machine Learning methods can be used to predict the spread of a virus based on the contact tracing data generated by the simulator. We show that in the case of available data it is possible to reduce the number of necessary PCR tests by around 98.7% and still discover around 96% of the positive cases.

Materials and Methods

Environment

We want to create a virtual environment that will resemble the spatial and demographic structure of a real city. The environment defines the space where agents will live and interact with each other.

To include the spatial information of real cities in our environment, we use data retrieved from OpenStreetMap.org [8]. It is also possible to use data from other sources, as long as the format meets the requirements: the data is in a tabular form, where each row contains the building's unique ID, district name, district id, coordinates and building type. Based on that data we build a virtual environment resembling the spatial structure of the city. An example of a virtual environment created on the data of the capital city of Armenia Yerevan is presented in Fig. 1.

Buildings can be public (restaurants, cafes, schools, etc) or residential. Residential buildings are divided into apartments. The number of apartments in each building is sampled from a predefined distribution. While it is possible to add more public buildings to the

configuration, the simulator must always have public buildings of the following types: school, university, work and hospital.

Fig. 1 The visualization of the geospatial data of Yerevan, Armenia used for creating the virtual environment. The orange boxes are the buildings belonging to their administrative districts. The color of each district represents the population in the respective district.

Agents

After creating the buildings, agents are distributed by district, according to the predefined demographic statistics for each district. During the distribution, each agent is assigned an apartment, age group, and gender. Age groups also determine whether the agent will have a location for work or study.

To simulate the mobility of the agents, we need them to move between districts and buildings and interact with agents. For this, we use the Mesa agent-based modeling framework [9]. Mesa uses discrete steps for simulation. During one simulation step, every agent performs a predefined set of instructions. In our case, each step corresponds to one hour, hence, we need to do 24 simulation steps to simulate one day.

In each step each of the agents does two operations: move and infect. Agents move to a building based on a probability distribution conditioned on the age group of the agent, day of the week, and the time of the day. By adjusting the probabilities it is also possible to enforce a lockdown by setting the probabilities of respective facilities to 0.

Disease transmission

After an agent finishes the moving step, a portion of agents which are in the same building or apartment is sampled as contacted agents (the contact probability is defined for each building type). If the agent is infected, we calculate the probability of its contacts getting infected according to [10]. Some of the parameters that contribute to the calculation of the

probability are room size, speaking frequency, loudness, whether people wear masks, etc. By default, the parameters are adapted for COVID-19 according to [10], but they can be adjusted for other diseases.

After infection, agents go through an incubation period, during which they don't have any symptoms and cannot infect other people. The incubation period is a random number of steps, sampled from a normal distribution with a default mean of 48 and a standard deviation of 7. After the incubation period is over, agents get severity status, which can be asymptomatic, mild, or severe, based on a predefined probability distribution. If the status is asymptomatic, agents continue to move as usual but can infect other agents. In case of mild severity, agents are quarantined in their apartments, and if the status is severe, they are taken to a hospital, where the possibility of dying is much lower. Hospitals have a finite maximum capacity. If there are no ICU beds available, agents are quarantined in their homes, until space becomes available and they are moved to a hospital.

If the infected agent does not die within a predefined number of days (about 10), they become more healthy, and cannot infect others or get infected. In that case, they are removed from the simulator, since they cannot affect the outcome of the simulator anymore.

Research results

We configured the simulator for the capital of Armenia, Yerevan. The city is divided into 12 districts, with a total population of 1080311 people [11]. We also configured information such as the age and sex distribution [12], and the number of residential buildings and apartments in each district [13] for the simulator. The number of cafes, universities, schools, offices, shops and other buildings is retrieved from the OpenStreetMap [8].

For the parameters that we couldn't find in open source databases (such as areas or volumes of the facilities, probability of having a contact in the facility, number of the total ICU beds, etc.), we used our judgment to assign approximate values, which later can be tuned to get the more accurate output.

We ran the simulator for 30 simulation days (i.e. 1440 steps) and logged only contacts of infected people. This generated around 3.4 GB of data.

Within those 60 days, we had 75333 infections 1631 of which died. We can also observe a higher death rate when there are no ICU beds available (Fig. 2).

To demonstrate how the simulator can be used for testing policies, we run the simulator for 31 days with different parameters and policies and with 100 initially infected agents. We summarize the results of the experiments below.

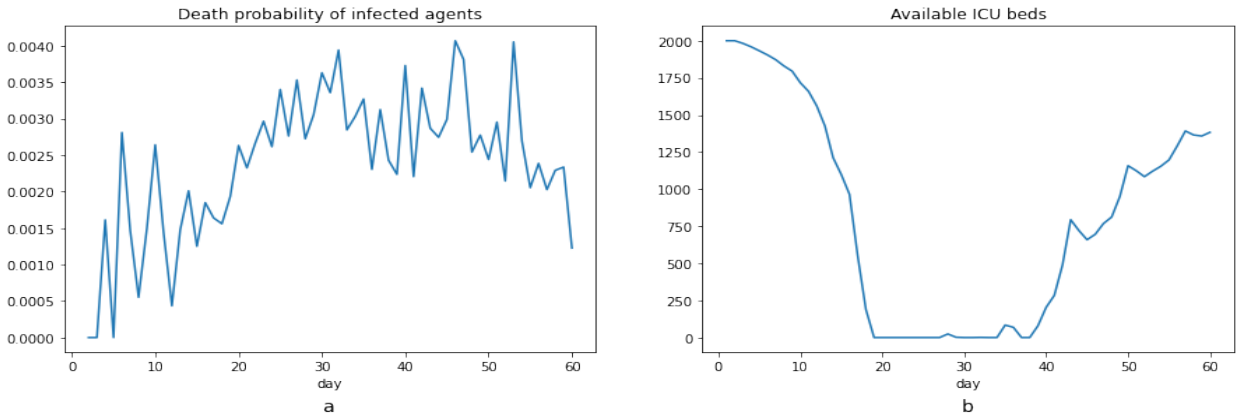

Fig. 2 There exists a moderate negative correlation of 0.625 between the probability of dying of infected agents (a) and the number of available ICU beds (b). When there are no beds available the probability of dying is higher.

- **Experiment 1** (Fig. 3 (a)): We run the simulator as usual without any restrictions. In 31 days around 7500 agents were infected and without any measures to stop the virus, the number of infections kept increasing.
- **Experiment 2** (Fig. 3 (b)): We introduced the mandatory mask policy from the first day till the last. In this case, the total number of infections was under 1000, and the infection wave died in around 20 days.
- **Experiment 3** (Fig. 3 (c)): the simulation started as usual and in day 15 we introduced the mandatory mask policy. We can see how the trend of infection changes from increasing to decreasing right after the mask mandate.
- **Experiment 4** (Fig. 3 (d)): the simulation started as usual, from day 15 cafes and gyms were closed. In this scenario no one wears masks, and we can see that while the trend changes after the policy change, the cases are still much higher compared to the mandatory mask mandate in experiment 3.
- **Experiment 5** (Fig. 3 (e)): There is a mandatory mask mandate from the first day, and the gyms and cafes are closed from day 15. In this scenario, closing gyms and cafes didn't have much impact, as on day 15 the infection wave was dying already.
- **Experiment 6** (Fig. 3 (f)): In this scenario, a full lockdown on all public facilities was introduced from day 15. As expected a full lockdown is effective and reduces the number of active cases to almost 0 within 15 days.
- **Experiment 7** (Fig. 3 (g)): In this scenario, there is a full lockdown and mask mandate from day 15. The mask mandate is not having an impact because of full lockdown agents don't have contact with other agents other outside their household.
- **Experiment 8** (Fig. 3 (h)): In this experiment, we enforce a mask mandate from the first day and a full lockdown from day 15. The full lockdown doesn't affect the curve for the same reason mentioned in experiment 5.

Next, we use the synthetic data generated by the simulator to train Machine Learning models for predicting the risks of people catching the virus, given that they had contact with an infected person.

The real-life scenario that we try to replicate with synthetic data is the following: a government is using a contact tracing application to identify contacts with infected people. The people who have contact with an infected person are tested for COVID-19 using a PCR test. For the sake of simplicity and without loss of generality we assume that everyone in the city uses the contact tracing application.

The government would like to reduce the number of necessary tests by using machine learning algorithms on the contact tracing data. The data has to be granular enough to give good enough predictions but at the same time needs to use features that are within ethical and legal bounds. For example, it cannot contain any information that can be used for personal identification.

For this, we clean and preprocess the 60-day data described in the previous subsection. After the preprocessing the data for training has the structure shown in Table 1. As we can see the data doesn't hold any personal features and cannot be used for personal identification.

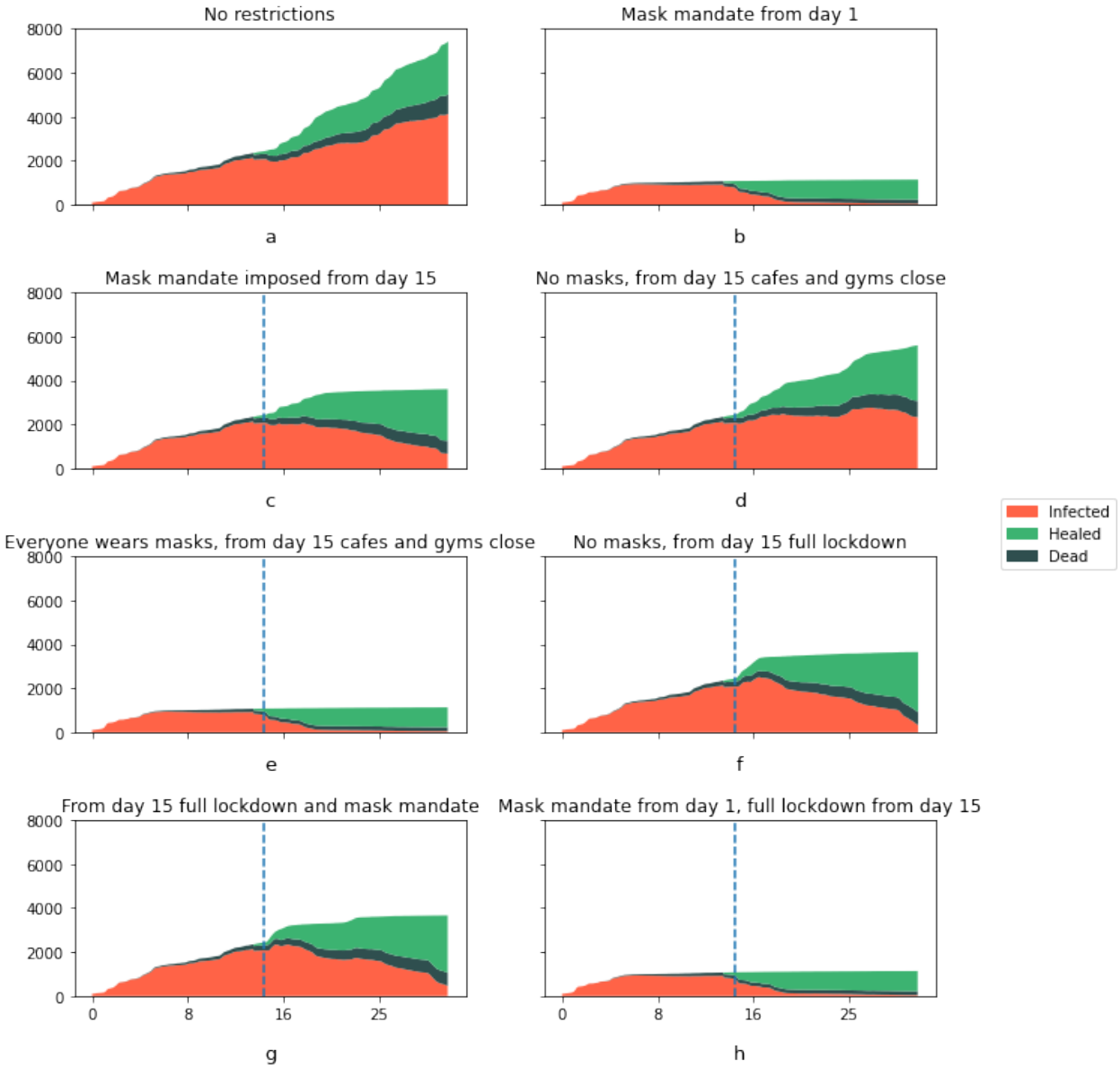

Fig. 3 Experiment results of different policies:
(a) No policies, (b) Mask mandate from day 1, (c) Mask mandate from day 15, (d) Cafes and gyms are closed from day 15, (e) Mask mandate from day 1, and cafes and gyms are closed from day 15, (f) Full lockdown from day 15, (g) Mask mandate and full lockdown from day 15, (h) Mask mandate from day 1 and full lockdown from day 15

Table 1

Confusion matrix on the test set

	0	1
0	7521327	950469
1	12624	12624

We use an XGBoost [14] model for training, with a max-depth of 4 and use positive class scaling to deal with class imbalance. We choose to use XGBoost as even after several years of its introduction, it is still one of the state-of-the-art methods for tabular data [15].

From the model's confusion matrix (Table 1) on the test set, we can see that we get around 96% of True Positive Rate (TPR) and 89% of True Negative Rate. This means that if we perform tests only on the agents predicted as positive by the model, we will need to do only 963093 tests instead of 8484957 and will miss only 537 positive cases. This means that we can reduce the number of required tests by around 98.7% and still detect 96% of the positive cases.

Conclusions

In this paper we introduced the novel Evid open-source, agent-based pandemic simulator that allows us to simulate pandemics on virtual replicas of real cities and tests policies before applying them in real life.

We also demonstrated with an example that the synthetic dataset can be used to develop ethical AI models for managing the pandemic. We developed an example model that helps us to reduce the number of necessary tests by around 98.7%. It is important to note that while this holds on a synthetic dataset, the number will be different in a real-world scenario because of less data availability and more noisy datasets.

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ՎԱՐԱԿԻՉ ՀԻՎԱՆԴՈՒԹՅՈՒՆՆԵՐԻ ՀԱՇՎՈՂԱԿԱՆ ՄՈԴԵԼԱՎՈՐՈՒՄ ԵՎ ԴՐԱՆՑ ՏԱՐԱԾՄԱՆ ԿԱՆԽԱՏԵՍՈՒՄ ՄԵԾ ՔԱՂԱՔՆԵՐՈՒՄ

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ԿՈՎԻԴ-19 համաճարակը աննախադեպ մասշտաբի համաշխարհային ճգնաժամ է: Կառավարությունները բախվեցին օրենքների պլանավորման և իրականացման մարտահրավերին՝ կապված դրանցում առկա անմիջական և արտաքին անորոշություններով: Նշված քաղաքականության հետևանքները հաճախ բացասական են եղել և որոշ դեպքերում էլ ավելի են սրել առողջապահական և տնտեսական ճգնաժամերը: Սույն հոդվածում ներկայացված է, թե ինչպես կարող է համակարգչային սիմուլյացիան օգտագործվել Երևանում տարբեր քաղաքականություններ փորձարկելու համար, նախքան դրանք իրական կյանքում կիրառելը: Ավելին, աշխատանքում նկարագրված է թե ինչպես կարելի է գտնել այն պարամետրերը, որոնք պահանջվում են առողջապահական կառավարման համար արդյունավետ և էթիկական արհեստական բանականության մոդելներ պատրաստելու համար: Վերջում ներկայացված է մեքենայական ուսուցման մոդել, որն օգնում է նվազեցնել անհրաժեշտ ՊՇՌ թեստերի քանակը մոտ 98,7%-ով:

Բանալի բառեր. ԿՈՎԻԴ-19, սիմուլյացիա, մեքենայական ուսուցում, հիվանդությունների մոդելավորում, ստրատեգիաների կառավարում, ագենտային մոդելավորում, առողջապահության կառավարում:

ВЫЧИСЛИТЕЛЬНОЕ МОДЕЛИРОВАНИЕ ИНФЕКЦИОННЫХ ЗАБОЛЕВАНИЙ И ПРОГНОЗИРОВАНИЕ ИХ РАСПРОСТРАНЕНИЯ В КРУПНЫХ ГОРОДАХ

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Пандемия COVID-19 - глобальный кризис беспрецедентного масштаба. Правительства столкнулись с проблемой разработки и реализации политики с большой неопределенностью в отношении ее прямого воздействия и внешних факторов. Последствия указанной политики часто были негативными, а в некоторых случаях еще больше усугубляли кризисы в сфере здравоохранения и экономики. В этой статье показано, как можно использовать компьютерное моделирование для проверки различных политик в Ереване, перед их применением в реальной жизни. Далее демонстрируется, как определить параметры, которые нужны для разработки эффективных и этичных моделей искусственного интеллекта для управления здравоохранением. Кроме того, представлена модель машинного обучения, которая помогает сократить количество необходимых ПЦР-тестов примерно на 98,7%.

Ключевые слова: COVID-19, моделирование, машинное обучение, моделирование заболеваний, стратегический менеджмент, агентное моделирование, управление здравоохранением.

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AGREGATE FOR STRIP TILLAGE OF SLOPE SOILS

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Abstract

A combined plowing unit with energy-saving universal working parts has been proposed for mountain farming, in particular for strip tillage of slope soil which will reduce topsoil dusting and overgrowth of inner layers, will ensure the water resistance of the loosened strip, will reduce soil erosion along which the removal of useful organic residues and herbicides will be provided and will increase soil fertility and crop yields.

The parameters of the placement of the working organs on the unit have been determined.

The use of a combined aggregate also solves environmental problems related to water-wind erosion in the fields during crop cultivation.

Key words: slope, strip tillage, universal, aggregate, working part, erosion.

Introduction

Modern agriculture is a rather complex and labor-demanding process that involves the application of various tillage systems the main ones being traditional, minimal, no-till and strip-till technologies.

Strip-till technology, unlike others, involves soil tillage by strips on which further cultivation is carried out. The use of this technology is effective because it increases the water resistance of the loosened layer, saves about 50% of the application of mineral fertilizers, nutrients are concentrated in the root zone of plants and yields increase by 25%. This technology is usually used once a year during autumn or spring loosening. In spring the cultivated strips should be sown with correct sowing machines [1].

Strip-Till technology is now widely used in advanced farms in the United States, Canada, Argentina, Germany and other countries [2].

The use of soil strip tillage technology is more effective in mountain farming as it is possible to create deep chisel zones that facilitate the penetration of surface water to the lower layers of soils helping to prevent water erosion.

Material and method

In order to ensure the water resistance and to prevent soil erosion of the sloping strip a combined slope-loosening unit of strip tillage is proposed (Fig. 1, a), on the frame (4) of which the combined working instruments arranged at a certain distance from each other are assembled, the working parts with flat hands for total soil loosening (3) and the flat discs (1) located in front of the combined sprockets are designed to facilitate the technological and dynamic stability of the agregate on the slope.

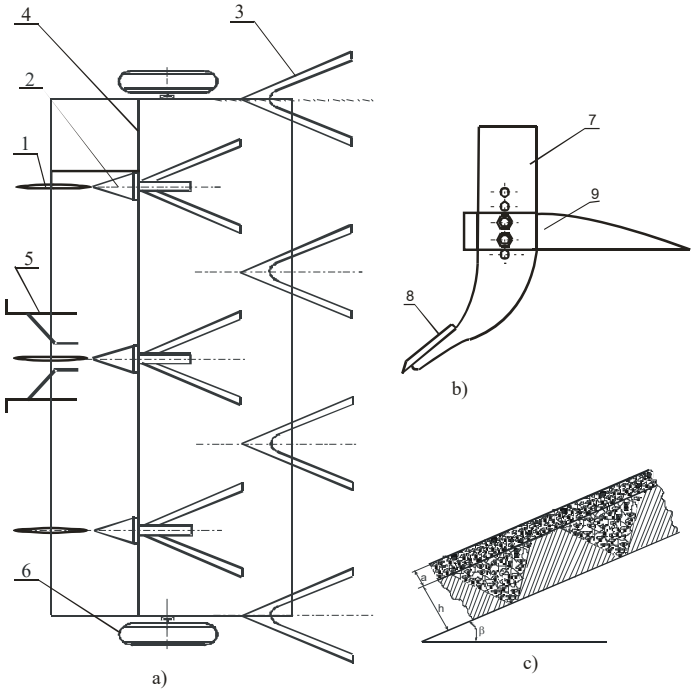

Fig. 1 Structure of combined agregate for strip tillage of the slopes

The combined working body (2), which is designed for strip tillage of the slope soil, consists of a stand (7) (Fig. 1, b), on which the digger-crusher (8) and the flat-cutter hoe (9) are assembled. The flat-cutter hoe (9) attached to the stand (7) performs a general deflection

of the top layer of the slope at a depth of a process and the digger-crusher (8) forms a V water-accumulating h depth (Fig. 1, c), where snowmelt water and rain waters accumulate.

When cultivating the soil with a combined slope cultivator, the water resistance of the loosened layer and the soil fertility increase, the soil erosion decreases and the removal of herbicides and useful organic residues takes place.

The combined slope tillage agregate performs two-layer soil loosening during the work. The top layer of soil is loosened with flat pads for total loosening to a depth of 8-12 cm and the bottom layer is loosened to a depth of 30-35 cm forming V-shaped water storage tanks at some distance from each other.

Results and analysis

Let us determine the placement parameters of working parts of agregate for clarifying their layout (Fig. 2).

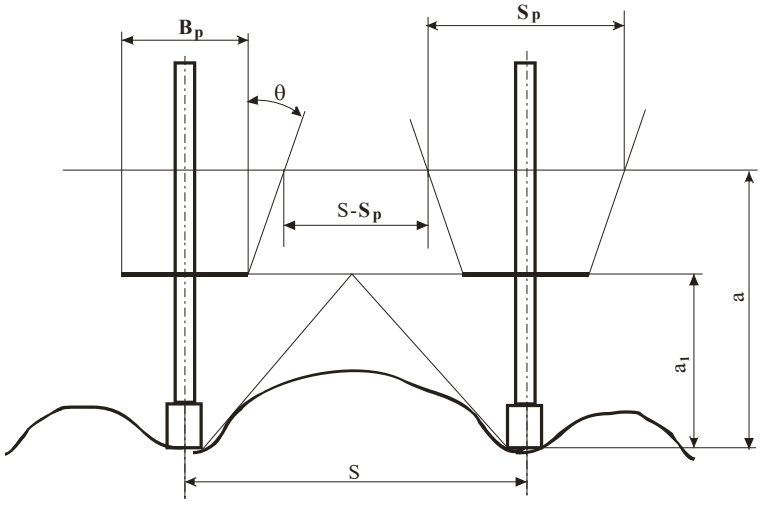

Fig. 2 Calculation sheme of layout of working parts

According to Fig. 2, the distance between the traces of combined working parts is determined by the following formula:

$$S = \left(S - S_p\right) + B_p + 2(a - a_1)tg\theta, \tag{1}$$

where B_p - is the width of coverage of flat digger, a - is the depth of tillage of loosened strips, a_1 - is the height of flat digger placement on the stand, S_p - is soil width tilled by flat digger, θ - is the angle of crack direction to the vertical in vertical-horizontal area.

The width of coverage of flat digger will be

$$B_p = S_p - 2(a - a_1)tg\theta, \tag{2}$$

According to agro-technical requirements, the width of cultivated strips should be within $0.25 \div 0.28m$. So when the depth of tillage is $a = 0.3m$, the height of flat digger placement on the stand $a_1 = 0.2m$, the angle of crack direction $\theta = 18°$, then the width of coverage of flat digger will be within $B_p = 0{,}18 - 0{,}24m$, and the distance between combined hoes is $S = 0{,}5 \div 0{,}56m$.

The working parts of the combined tillage unit must be arranged in such a way as to exclude the accumulation of soil between them. In order to prevent the accumulation of soil between the drill hoes and the flat disks placed in front of them in the proposed unit, it is necessary to place these working parts at a certain distance in the direction of action. This distance is determined by the length of crack of deformed strip of the soil (l') (Fig. 3).

$$L = l\cos\alpha + l', \tag{3}$$

where l - is the length, l' - is length of crack of deformed strip of the soil which was determined by the dimensional condition of soil deformation:

$$l' = \frac{a}{\sin\psi}\cos\psi, \quad \text{or} \quad l' = a\,ctg\,\psi, \tag{4}$$

where a - is tillage depth, ψ - is the angle of crack direction of deformed soil to the direction of agregate action which is determined by the following expression (Fig. 3) [3, 4].

$$\psi = 90^0 - \frac{\alpha + \varphi + \varphi_1}{2}, \tag{5}$$

where φ - is contact angle of soil and metal, φ_1 - is the angle of soil internal contact.

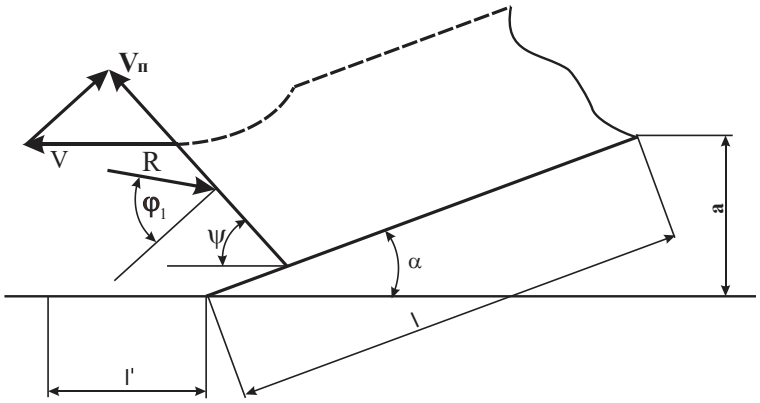

Fig. 3 Scheme of determining the distance between working organs to the direction of tillage unit

Inserting (4) and (5) in (3) we will get

$$L = l\cos\alpha + a\,tg\,\frac{\alpha+\varphi+\varphi_1}{2} \tag{6}$$

The research showed that working part of hoe for deep tillage of dark soils should have $\alpha = 20 - 25^o$ loosening angle and 0.2m length [4, 5, 6], hence according expression (6), the distance between the working parts to the direction of tillage unit action will be $L = 0.58 - 0.66m$.

Conclusion

1. In case of tillage with the proposed two-strip tillage unit, both topsoil dusting and over-condensation of soil internal layer are reduced, water resistence is ensured, soil erosion

and soil washing are reduced and the removal of herbicides and useful organic matter is noted and the fertility of the soil is increased.

2. The application of combined aggregate solves a number of ecological issues connected with the water and wind erosion occurred in fields during crop cultivation.
3. In order to exclude the accumulation of soil between the drill hoes and the flat disks placed in front of them in the proposed unit, it is necessary to place these working parts at a distance of 0.58 - 0.66 m in the direction of action.

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ԼԱՆՋԵՐԻ ՀՈՂԻ ՇԵՐՏԱՎՈՐ ՄՇԱԿՄԱՆ ԱԳՐԵԳԱՏ

Տոնապետյան Պ.Ա.[1], Գասպարյան Պ.Յու.[2], Տոնապետյան Ա.Պ.[1], Առաքելյան Ա.Ա.[1]

[1]Հայասանի ազգային ագրարային համալսարան

[2]Շուշիի տեխնոլոգիական համալսարան

Լեռնային երկրագործության, մասնավորապես՝ լանջերի հողի մշակման համար առաջարկվել է շերտավոր մշակման կոմբինացված ագրեգատ, էներգախնայող ունիվերսալ բանող օրգաններով, որոնց կիրառմամբ կնվազի հողի վերին շերտի

փոշիացումը, ներքին շերտերի գերխտացումները, կապահովվի փխրեցվող շերտի ջրակայունությունը, կնվազի հողի էրոզիան, իսկ դրա հետ նաև՝ հերբիցիդների և այլ օգտակար օրգանական մնացորդների հեռացումը, կբարձրանա հողի բերրիությունն ու մշակաբույսերի բերքատվությունը:

Որոշված է ագրեգատի վրա բանող օրգանների տեղակայման պարամետրերը:

Կոմբինացված ագրեգատի կիրառումը լուծում է նաև էկոլոգիական խնդիրներ՝ կապված մշակաբույսերի մշակման ժամանակ դաշտերում առաջացող ջրային և քամու էրոզիայի հետ:

Բանալի բառեր. լանջ, շերտավոր մշակում, ունիվերսալ, ագրեգատ, բանող օրգան, էրոզիա:

АГРЕГАТ ДЛЯ ПОСЛОЙНОЙ ОБРАБОТКИ ПОЧВЫ НА СКЛОНАХ

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Для горного земледелия, в частности, для обработки почвы на склонах, предложен комбинированный агрегат с энергосберегающими универсальными рабочими органами для послойной обработки почвы, с применением которого уменьшится распыление верхнего слоя почвы, уплотнение внутренних слоев, будет обеспечена водоустойчивость взрыхленного слоя почвы, уменьшится эрозия почвы, а вместе с ней и вынос гербицидов и других полезных органических остатков, повысится плодородие почвы и урожайность культур.

Определены параметры размещения рабочих органов на агрегате. Применение комбинированного агрегата решает также экологические проблемы, связанные с водной и ветровой эрозией полей при возделывании сельскохозяйственных культур.

Ключевые слова: склон, послойная обработка, универсальный, агрегат, рабочий орган, эрозия.

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- Հետազոտությունն իրականացվել է ԱՀ ԿԳՄՍ նախարարության կողմից տրամադրվող ֆինանսական աջակցությամբ՝ №SCS20-007 «ԱՀ Լեռնային երկրագործությունում հողի մշակման նոր էներգախնայող տեխնոլոգիայի և լիակատար մեքենայի մշակում և արտադրական փորձարկում» գիտական թեմայի շրջանակներում:

- Исследование было проведено при финансовой поддержке Министерства ОНКС Республики Арцах в рамках научной темы № SCS 20-007 "Разработка и производственные испытания новой энергосберегающей технологии обработки почвы и комбинированной машины в Горном земледелии РА".

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ANALYSIS OF METHODS FOR DETERMINING DRIVER FATIGUE AND A WAYS OF THEIR IMPROVEMENT

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Abstract

The safety of road transport is the main component of the security system for each state. The low level of road safety has a significant impact on the safety of the community.

Studies have been carried out on the etiology of road traffic accidents. They showed that as a result of the increase in traffic intensity and the increase in the number of drivers, there is an increase in the number of traffic jams which in turn leads to additional driver fatigue and, in some cases, to sleep.

There is a need to take some measures to prevent traffic accidents due to fatigue and sleep. When studying such modern systems, it becomes clear that they work by analyzing the actions of the driver and the course of the car.

The aim of the work is to conduct a comparative analysis of methods for determining driver fatigue and developing a new additional method.

The paper shows that the main disadvantages of the systems under study are: complex design; adaptation to the driver; fatigue settling time and high system cost. It is proposed to introduce a pulse fatigue detection system (PFDS), which, by analyzing the number of pulse beats, will predict human fatigue and possible sleep, which will lead to a simpler design in systems with control of physiological parameters, that is-to reduce the price.

Key words: traffic accident, fatigue, sleep, driver fatigue monitoring systems.

Introduction

38568 road accidents were registered in Armenia, as a result of which 3543 people died and 55230 were injured from 2011 to 2021. The statistics for these 10 years are presented graphically below [1].

An increase in the number of drivers and a sharp increase in traffic volume have currently contributed to an increase in traffic jams which in turn leads to driver fatigue while driving, which causes an increase in the number of traffic accidents. Based on this, it is necessary to develop measures that will help reduce the number of road accidents. Therefore, the study and comparative analysis of methods and algorithms for building driver fatigue control systems is an urgent task.

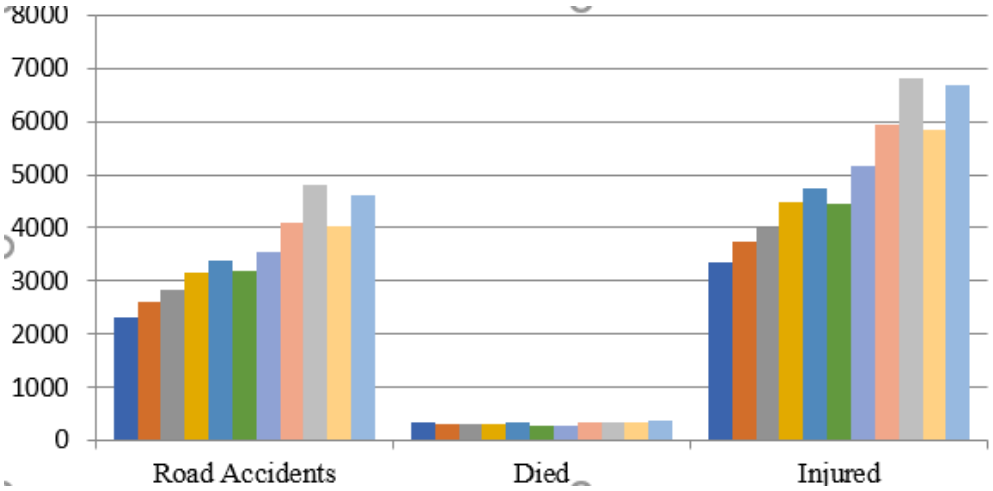

Fig. 1 Statistics of road accidents registered in the RA and injured as a result of them from 2011 to 2021

Conflict setting

The main reason for the fatigue of most drivers is incomplete sleep. 5-25% of all traffic accidents are caused by driver fatigue [2]. At the same time, road traffic accidents caused by driver fatigue usually have more severe consequences than road traffic accidents for other reasons. According to Ford experts, drivers who slept less than 4 hours were 11.5 times more likely to be involved in a traffic accident [3]. Many experts compare sleep driving to drunk driving. Such a comparison is presented below.

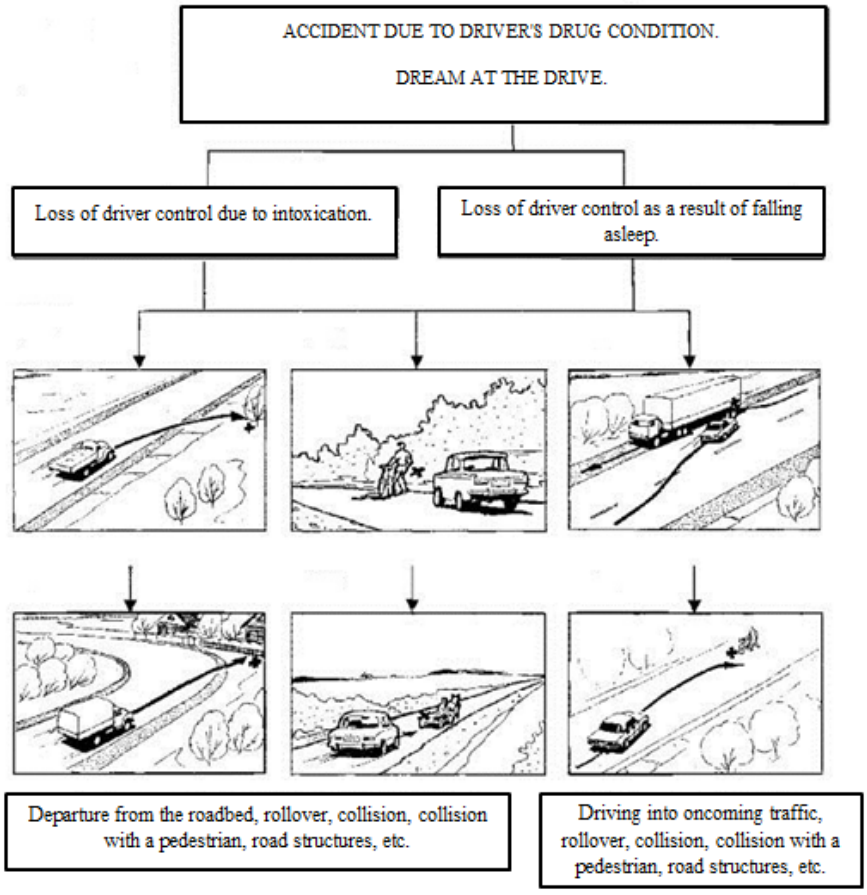

Fig. 2 Drunk or sleep driving accidents [4]

In order to reduce the likelihood of all this, a system should be developed that will make the driver feel tired and take the necessary steps to prevent possible traffic accidents.

The article aims to analyze methods for determining driver fatigue and develop a new auxiliary method.

Materials and methods

Driver reliability is understood as the ability to timely and accurately receive and process information about the state of vehicles, road conditions, as well as make and implement adequate decisions on driving a car for a given period of time with acceptable levels of labor intensity and the risks of an emergency [5].

One of the reasons for the incorrect actions of the driver is his current functional state during the execution of activity algorithms. To improve traffic safety, it is desirable to limit or completely block access to driving a vehicle in the presence of such factors. To carry out this task, special systems and tools are called upon to control the state of the driver which a number of automakers equip their cars with.

In this work, we will consider the operation of existing systems, their disadvantages and advantages by a comparative method. Then, analyzing it, an attempt will be made to propose a new auxiliary method.

Research results

Fatigue measurement systems which use the method of assessing involuntary deviations from the ideal trajectory while driving, take various parameters as a basis for assessing drowsiness. As a rule, this is an analysis of the change in the angle of rotation of the steering wheel and an analysis of the position of the car on the roadway.

The main disadvantages of systems that take the position of the vehicle on the road as the main parameter is that their operation is based on recognizing the signs of fatigue of a particular driver, as well as the complexity of their training and adaptation for each driver. In addition, these systems are not suitable for use in vehicles used by more than one driver. They cannot be used in cars of other brands to receive information about the driver's condition from auxiliary sensors (steering wheel position, gas pedal, etc.) which may not be compatible with other car brands. Another disadvantage of the systems is their high complexity, cost limiting application and high structural and functional redundancy.

Methods for automatically determining the degree of driver fatigue, which are based on automatic analysis of the characteristics of the visual analyzer, use cameras and an on-board computer. The main parameters are blinking (calculate in a predetermined time interval), direction of gaze tilt of the head (when falling asleep standing or sitting, the head leans forward a little, if the device detects that the angle of inclination forward has changed by a certain degree, then it beeps); scalogram (the orientation of the optical axis of the eyeball in space is determined) [6].

The disadvantage of these methods is significant computational complexity, which makes it difficult to implement them in the built-in on-board computing facilities of a car that do not have sufficient computing power. Increased time to receive a sleep signal due to the relatively long process of eye detection (calculations must be done in real time, given that the driver can turn his head, wear glasses, drive through tunnels or brightly lit areas, etc.).

Another direction provides for the additional equipment of a car with special biometric sensors that allow assessing the general physical condition of a person according to such parameters as respiratory rate, heart rate, skin conductivity, etc. Evaluation of the combination

of these parameters helps to determine the degree of driver stress. These systems are more complex, but also more promising, since they evaluate the real state of a person according to biological indicators and not according to algorithms of actions (as in the first direction).

The disadvantage of systems based on the control of physiological parameters is the need to use complex sensors built into the seat and steering wheel and biometric sensors which require physical contact with the human body [7].

Let's take a look at these methods in comparison.

Table 1

Comparison of some methods for determining driver fatigue

Options	Method for assessing involuntary deviations	Method for analyzing the characteristics of the visual analyzer	Control method of physiological parameters
Adaptation to the driver	-	-	+
Determination time	-	-	+
Simplicity of design	-	-	-
Physical contact	+	+	-
Price	-	-	-

Analyzing the comparison of methods, it becomes clear that the most promising and error-free will be control systems that combine the features and advantages of all directions at once. But at the same time, the complexity of the design and the price of the system remain disadvantages.

Certain changes occur in the body during fatigue and after and during sleep. One of the main changes is the reduction in the number of heartbeats. The number of pulse beats depends on age, gender, body weight, etc. On average, the number of normal human pulse beats ranges from 60-90. But depending on gender and age, it varies. All this is presented in the table below.

Table 2

Pulse beats according to sex and age [8]

Age	In a calm state		During physical exertion	
	men	women	men	women
20-40	60-75	65-80	190-200	230-240
40-60	70-85	75-90	160-180	200-220

The number of heartbeats changes when a person begins to sleep. When a person begins to sleep, his pulse can decrease by 1.5 times and reach up to 30 beats per minute.[9] That is, by analyzing a person’s pulse, one can understand the degree of fatigue and the likelihood of the driver falling asleep at the wheel. To analyze the pulse, you need to understand how it can be measured. Proceeding from this, a method based on the providence of measurements of the driver's pulse is proposed. The proposed method is as follows:

- Pulse sensors are installed on the steering wheel,
- at the beginning of driving, the pulse is counted,
- in the process of driving, the pulse is periodically counted and compared with the initial number,

- if as a result of the comparison it turns out that the pulse is underestimated, then a danger signal is issued.

Let's call it the Pulse Fatigue Detection System (PFDS).

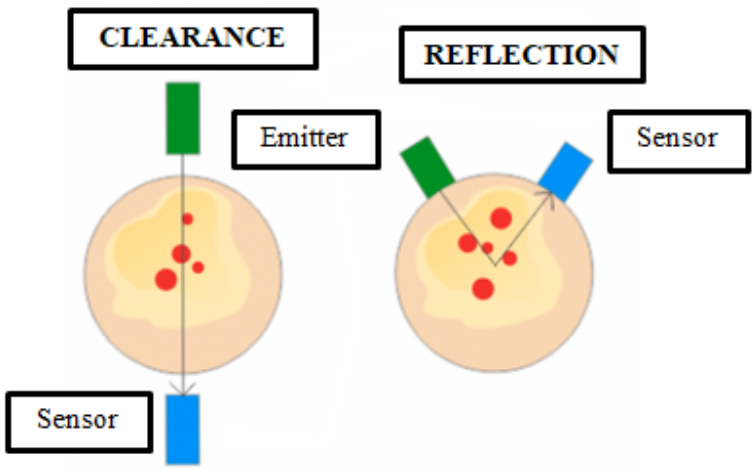

Fig. 3 Scheme of operation of the pulse sensor in the PFDS system

Since these sensors are small in size, it is proposed to install them in the steering wheel to measure the pulse from the driver's fingers.

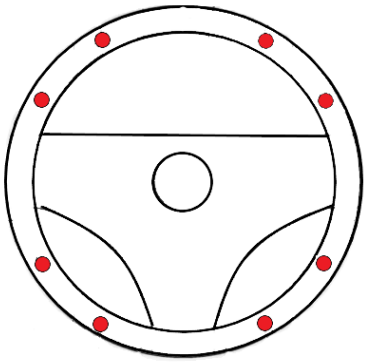

Fig. 4 The main places of the sensors

To do this, the sensors need to be placed in the optimal parts of the steering wheel where drivers hold the most. With the introduction of this PFDS system, based on the physiological characteristics of a person, it will be possible to determine the degree of his fatigue and favorable health for driving, and in case of failure to take appropriate measures to stop the car. This method can be used in the method of monitoring the physiological parameters of the driver's tension.

The driver's physical tension is evaluated by processing a variety of parameters:

- vehicle movements (speed, longitudinal and lateral acceleration, yaw rate),
- driver actions (steering wheel angle, position of the accelerator pedals and brakes),
- road conditions (traffic density, nature of the road surface),
- biometric indicators (heart rate, respiratory rate, skin temperature).

If the load on the driver is high enough, the system takes measures to reduce stress, including automatically starting the function of blocking the mobile phone from incoming calls (do not disturb function).

Conclusions

1. A comparative analysis of existing methods for determining driver fatigue was carried out in the work during which it turned out that their main disadvantages are a complex design, adaptation to the driver, fatigue settling time and high cost of systems.
2. A method of PFDS is proposed, which, by analyzing the number of pulse beats, will predict human fatigue and possible sleep.
3. A simple design of a system for monitoring physiological parameters leading to a price reduction is proposed.

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ՎԱՐՈՐԴԻ ՀՈԳՆԱԾՈՒԹՅԱՆ ՈՐՈՇՄԱՆ ՄԵԹՈԴՆԵՐԻ ՎԵՐԼՈՒԾՈՒԹՅՈՒՆ ԵՎ ԴՐԱՆՑ ԿԱՏԱՐԵԼԱԳՈՐԾՄԱՆ ՏԱՐԲԵՐԱԿԸ

Պողոսյան Վ.Գ.
Հայաստանի ազգային պոլիտեխնիկական համալսարան

Ավտոմոբիլային տրանսպորտի անվտանգությունը յուրաքանչյուր պետության համար անվտանգության համակարգի հիմնական բաղադրիչն է: Ճանապարհային անվտանգության ցածր մակարդակը էական ազդեցություն ունի համայնքի անվտանգության վրա:

Ուսումնասիրություններ են կատարվել ճանապարհատրանսպորտային պատահարների պատճառաբանության վերաբերյալ: Նրանք ցույց են տվել, որ երթևեկության ինտենսիվության բարձրացման և վարորդների թվի ավելացման արդյունքում նկատվում է խցանումների աճ, ինչն իր հերթին հանգեցնում է վարորդների լրացուցիչ հոգնածության, իսկ որոշ դեպքերում՝ քնի:

Հոգնածության և քնելու հետևանքով ճանապարհատրանսպորտային պատահարները կանխելու համար անհրաժեշտ է որոշակի միջոցներ ձեռնարկել: Նման ժամանակակից համակարգերն ուսումնասիրելիս պարզ է դառնում, որ դրանք աշխատում են վարորդի գործողությունները և մեքենայի ընթացքը վերլուծելով:

Աշխատանքի նպատակն է իրականացնել վարորդների հոգնածության որոշման մեթոդների համեմատական վերլուծություն և մշակել նոր օժանդակ մեթոդ:

Աշխատանքում ցույց է տրված, որ ուսումնասիրվող համակարգերի հիմնական թերություններն են՝ բարդ կառուցվածքը, վարորդին հարմարվելը, հոգնածության որոշման ժամանակը և համակարգի բարձր արժեքը: Առաջարկվում է ներդնել հոգնածության որոշման պուլսային համակարգ (ՀՈՊՀ), որը վերլուծելով զարկերակային զարկերի քանակը՝ կկանխատեսի մարդու հոգնածությունը և հնարավոր քունը, ինչը կհանգեցնի ֆիզիոլոգիական պարամետրերի վերահսկմամբ համակարգերի ավելի պարզ դիզայնի, այսինքն՝ գինը նվազեցնելու համար:

Բանալի բառեր. ճանապարհա-տրանսպոչտային պատահար, հոգնածություն, քուն, վարորդի հոգնածության մոնիթորինգի համակարգեր:

АНАЛИЗ МЕТОДОВ ОПРЕДЕЛЕНИЯ УСТАЛОСТИ ВОДИТЕЛЯ И ВАРИАНТ ИХ ДОРАБОТКИ

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Безопасность автомобильного транспорта для каждого государства является главным компонентом системы безопасности. Низкий уровень безопасности дорожного движения оказывает значительное влияние на обеспечение безопасности общества.

Были проведены исследования причин дорожно-транспортных происшествий. Они показали, что в результате повышения интенсивности движения и увеличения числа водителей наблюдается увеличение количества пробок, что, в свою очередь, приводит к дополнительной усталости водителей, а в некоторых случаях, ко сну. Необходимо принять определенные меры для предотвращения дорожно-транспортных происшествий, вызванных усталостью и сном. Изучая такие современные системы, становится ясно, что они работают, анализируя действия водителя и движение автомобиля.

Цель работы - провести сравнительный анализ методов определения утомляемости водителей и разработать новый вспомогательный метод.

В работе показано, что основными недостатками исследуемых систем являются сложная структура, адаптация к водителю, время определения усталости и высокая стоимость системы. Предлагается внедрить пульсовую систему определения усталости (ПСОУ), которая, анализируя количество ударов пульса, будет прогнозировать утомляемость человека и возможный сон, что приведет к упрощению конструкции в системах контроля физиологических параметров, то есть к снижению цены.

Ключевые слова: дорожно-транспортное происшествие, усталость, сон, системы контроля усталости водителя.

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TRANSPORTATION AS A DISCREET SYSTEM

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Abstract

Numerous procedures concerning the transport develop as accidental events the result and course of which depend on many occasional reasons.

Transport procedures are considered to be a cyclic random processes in discreet condition, that is why we suggest to use the Markov chain characteristics during the research as the transition from any S_i situation to S_{i+1} situation does not depend on how and when the system has passed to S_i situation.

Key words: transport, process, event, occasional, character, chain, characteristics.

Introduction

Transportation carries raw materials, fuel, materials, semi-finished products, consumer goods and other goods ensuring the production activities of all enterprises and organizations and the delivery of their products to consumers, while the products of one can be raw materials for another. In this way, transport facilitates the establishment of economic-production ties between the separate branches of enterprises [1,2].

Conflict setting

The task of improving the management of transport processes as a whole is very difficult, but objective conditions are offered for its solution at present. In practice, economic-mathematical methods are widely used for the planning of trucking, which allows you to select the best options for the organization of work and to identify available resources. Automated control systems are being successfully introduced in the field of transport.

The analysis of transport processes shows that there are a number of shortcomings in the system of organization of mass cargo transportation, which lead to unreasonable planning of the transport process and inefficient organization of rolling stock work.

Research results

In practice, the task for each car indicates the object of work, that is, the route and the number of passes during the shift.

The calculation of the shift work is made in the following expressions:

$$Q = \frac{T_r q \gamma \beta V_t}{l_c + \beta V_t t_{lu}}, \quad (1)$$

$$P = \frac{T_r q \gamma \beta V_t l_c}{l_c + \beta V_t t_{lu}}: \quad (2)$$

The analysis of these formulas shows that as the time in the schedule increases, the number of products increases linearly.

Considering the full-empty reciprocating swing route and the vehicle operating in it as a system (micro-system), it can be noted that such a system under the influence of the work done by the car successively switches from state S_0 (if no march) to state S_z (when performed n marches).

It should be noted that in the process of transportation, a transport product is created simultaneously which is measured as the amount of transported cargo or tons of work done.

The creation of a transport product takes place during the time when the loaded vehicle is moving from the loading point to the destination. However, as soon as the car stops for unloading, the production stops and resumes at the next exit of the car from the loading point.

The change in product quantity over time is shown in Fig. 1.

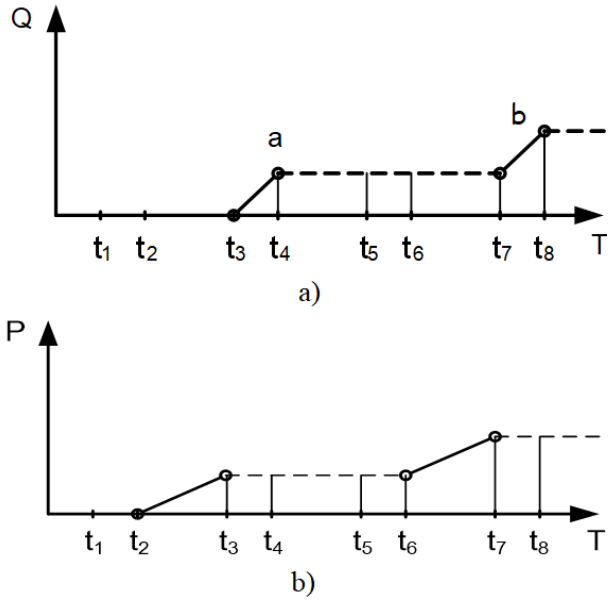

Fig. 1 Actual change over time

a - amount of transported cargo,
b - transport work performed

At that moment of t_1, the car stops for the first load, which ends at the moment of t_2. Arrival at the destination is determined by the moment at which unloading begins. The load is considered to have been delivered when the unloading is completed (at the moment of t_4) and the quantity of the load is shown in point a (Fig. 1 a).

Then the car leaves for the next loading and reaches the loading point at the moment of t_5. From here the actions of the transport process are repeated, and the moment t_8 corresponds to the performance of the next march. At the point of destination there will now be a load equal to the sum of the quantities of cargo transported during the two marches, which is determined by the ordinance of point b.

When observing the process of preparation (creation) of a transport product (t/km), we will notice that from time t_1 to time t_2 that product is not created (Fig. 1 b). It is produced from time t_1 to time t_2, as long as the car is in motion with the load, after which the production of the product stops. The preparation of the transport product is resumed at the moment of leaving the cargo point during the movement of the car. Output increases as load increases.

According to the presented schedules, the stages of receiving this or that transport product do not coincide, they are not continuous. The product manufacturing process corresponds to an intermittent linear dependence.

Many actions in this process develop as random events the outcome and course of which depend on many random causes. The transition from one situation of the system to another is by "flight" and, since each process can be counted (numbered), then the transport process is considered an intermittent process.

If we look at the system as an example of an FIT, it can go to a new situation at any unknown accident. In this regard, it should be noted that the transport process is a random discrete process at a constant time; and at the same time, the features of the Markov chain are unique to it because the transition from S_i situation to any S_{i+1} situation does not depend on when and how the system passed to the situation S_i [3, 4].

The graph of the state of the transport process as the system used for each vehicle is shown in Fig. 2.

Fig. 2 Graph of transport process condition

S_1- one march is done, S_i- i march is done, S_n- n march is done

According to the constructed graph, the system switches from situation S_0 unilaterally to the following situations.

S_1 - 1 march was made,

S_i - i march was performed,

S_n - n march performed.

However, with each shift or every day, such a system goes back to normal S_0 condition. This transition can be made from any S_i state. Moreover, if the number of trips i is equal to the planned number, then the shift (day) plan is fulfilled, otherwise it is not fulfilled or is overfulfilled. Therefore, the transport process is considered to be a cyclically random process with a discrete state which is characterized by the number of complete marches in any period [1, 2, 4].

If we denote the probability P_{ij} of passing from situation S_i to situation S_j in one step, and the probability P_{ii} of delay in state S_i. Moreover, in this case the step is considered to be

the completed walk, and P_{ii} - is a function of the length of the load, the speed of transport work and the loading-unloading line.

Knowing the probabilities of these quantities, one can calculate the probability of switching from system situation S_i to situation S_j at time t_k. In other words, the magnitudes of the probabilities of passing all pairs λ_{ij} of situation can be found S_i S_j by these quantities.

Knowing the quantities λ_{ij}, we can make a graph describing the situation of the system, which, in turn, will allow to determine the probabilities of these situations as functions from t [2, 3].

$$P_1(t), P_2(t), \dots, P_n(t):$$

We show the system of equations for the graph under discussion (Fig. 2).

$$\left.\begin{aligned} P_0 &= \frac{1}{1+\lambda_{01}\left(\frac{1}{\lambda_{12}}+\frac{1}{\lambda_{23}}+\cdots+\frac{1}{\lambda_{0n}}\right)}, \\ P_1 &= P_0\frac{\lambda_{01}}{\lambda_{12}}, \\ P_1 &= P_0\frac{\lambda_{01}}{\lambda_{23}}, \\ &\cdots\cdots, \\ P_i &= P_0\frac{\lambda_{01}}{\lambda_{ii+1}}, \\ P_n &= P_0\frac{\lambda_{01}}{\lambda_{n0}}: \end{aligned}\right\} \quad (3)$$

The formulas express the marginal probabilities of this cyclical process. The description can be presented in a more convenient way if we use the average time $\bar{t}_i$ of the system S_i to be in place instead of λ_{ij}.

If the process is Markovian, then the law of time distribution does not depend on how long the system has been in a particular S_i situation. This means that the system is as it would be if the system were in a state of flux and that is nothing but a demonstrative law of the T - time distribution between adjacent events.

The parameter of that law is $\lambda_{i,i+1}$, and the average time of system is in S_i state.

$$t_i = \frac{1}{\lambda_{ii+1}} \quad (4)$$

From here

$$\lambda_{ii+1} = \frac{1}{t_i} \quad (5)$$

when, $i = n$ then by cycling

$$\lambda_{n0} = \frac{1}{t_n} \quad (6)$$

Putting these expressions in $P = \frac{T_r q \gamma \beta V_t l_c}{l_c + \beta V_t t_{lu}}$ and making changes, we get

$$P_0 = \frac{\bar{t}_0}{\bar{t}_0+\bar{t}_1+\cdots+\bar{t}_n}, \quad (7)$$

$$P_1 = \frac{\bar{t}_1}{\bar{t}_0+\bar{t}_1+\cdots+\bar{t}_n}, \quad (8)$$

or in general $$P_k = \frac{\bar{t}_k}{\sum_0^n \bar{t}_i}. \quad (9)$$

Thus, the marginal probabilities of states in a cyclic system are considered as the mean of the system times in each situation. The marginal probability of the system is the totality of the plan and forecast. In this case, the forecast is a tool (or a set of different ways) by which the system reaches this or that situation, and the plan is one of the most chosen (directive) directions to reach the probable state of the system.

Conclusion

1. Transport procedures are considered to be a cyclic random processes in discreet condition, that is why we suggest to use the Markov chain characteristics during the research as the transition from any S_i situation to S_{i+1} situation does not depend on how and when the system has passed to S_i situation.
2. An AMC can be presented as a system combining multiple routes on any business day each of which corresponds to a certain graph of condition. It is proposed to construct a similar graph for the AMC, that is the AMC system can also be in the S_0 state and subsequently switch to the S_i situation, returning to the S_0 situation by cyclic equation.

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ՏՐԱՆՍՊՈՐՏԱՅԻՆ ԳՈՐԾԸՆԹԱՑԸ ՈՐՊԵՍ ԴԻՍԿՐԵՏ ՎԻՃԱԿՈՎ ՀԱՄԱԿԱՐԳ

Հակոբյան Բ.Դ., Գասպարյան Ա.Պ.
Շուշիի տեխնոլոգիական համալսարան

Տրանսպորտային գործընթացի բազմաթիվ գործողություններ զարգանում են որպես պատահական իրադարձություններ, որոնց ելքը և ընթացքը կախված են պատահական բնույթի շատ պատճառներից:

Տրանսպորտային գործընթացը համարվելով ցիկլիկ պատահական գործընթաց՝ դիսկրետ վիճակով, առաջարկվում է ուսումնասիրության ժամանակ կիրառել Մարկովի շղթայի հատկանիշները, քանի որ ցանկացած S_i վիճակից S_{i+1} վիճակին անցումը կախված չէ, թե երբ և ինչպես է համակարգն անցել S_i վիճակին:

Բանալի բառեր. տրանսպորտ, գործընթաց, իրադարձություն, պատահական, բնույթ, շղթա, հատկանիշ:

ТРАНСПОРТНЫЙ ПРОЦЕСС КАК СИСТЕМА С ДИСКРЕТНЫМ СОСТОЯНИЕМ

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Многие операции транспортного процесса развиваются как случайные события, ход и исход которых зависит от многих причин случайного характера.

Рассматривая транспортный процесс как циклический случайный процесс с дискретным состоянием, предлагается в ходе исследования применить свойства Марковской цепи, так как переход из любого состояния S_i в состояние S_{i+1}не зависит от того, когда и как система пришла в состояние S_i.

Ключевые слова: транспорт, процесс, событие, случайный, характер, цепь, свойство.

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RELIABILITY OF THE PROCESS OF URBAN TRANSPORTATION AND INDICATORS OF EVALUATION

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Abstract

There are various types of disruptions in the urban transportation process which lead to dynamic imbalances reducing the level of reliability of the transportation process.

In order to increase reliability, it is necessary to determine the factors that cause the failure of the transport company.

It is recommended to evaluate the reliability of urban transportation according to the stages of the transportation process (line omission, line work), and then developing appropriate methods for evaluating the system of indicators for the whole process.

***Key words*:** transport, public, passenger, process, index, reliability.

Introduction

Experience in the operation of urban public passenger transport shows that both the quality of service to the population and the technical and economic indicators of passenger transport work are greatly influenced by the level of reliability of the transportation process.

Studies have shown that the level of reliability of the urban public transportation process is affected by the number of line failures, the number of interruptions during work on the route, their interval and the line (line work) recovery time etc. [1,4,5].

Conflict setting

The most important task to increase the reliability of the transportation process is to reduce the number of line omissions, breakdowns during work and their recovery time. The solution to the problem is possible by determining the factors that cause the failure of the transport enterprise.

Research results

Determining the combined effect of factors on the number of failures in the transport process requires the construction of a multifactorial regression model where the dependent variable Q (number of failures) is considered as a function of the independent variables x (factors) [3].

The dependence of the factors on the number of failures can be expressed by the Q (X) function, denoting the random factors $x_1, x_2, \dots x_i$. If we assume that the relationship between X and Q is linear, then the regression equation will look like this

$$Q(X) = a_0 + a_1 x_1 + a_2 x_2 + \cdots + a_i x_i.$$

The given equation relates the average value of the Q (X) function to each random factor x_i.

The coefficients of the regression equation $a_1, a_2, \dots, a_i$ take into account the magnitude of the influence of each factor on the number of failures in the transport process [5].

The destabilizing factors affecting the reliability of the urban public transportation process are due to the influence of both external and internal environments.

The external factors affecting the reliability of the urban public transportation process are:

1. The impact of the time of year on the operation of rolling stock (RS). During the autumn and winter seasons, due to the technical unpreparedness of the RS, the frequency of dropping out of the car park decreases and the number of rejections increases due to low temperatures.
2. Weather conditions. With the worsening weather conditions (heavy snowfall, heavy rains, fog) the visibility and the speed of movement of the RS decreases, the malfunctions and the traffic accidents increase.

   It is practically impossible to eliminate the negative impact of environmental factors by urban passenger transport companies which is mainly due to objective reasons (weather conditions etc.).
3. High level of urbanization of the city and low level of road-transport development which leads to a sharp increase in traffic density and intensity. The latter lead to a high intensity of traffic, which reduces the speed of traffic and increases the number of possible accidents leading to passenger delays.
4. Off-site construction works carried out by other organizations in the street traffic which also leads to delays in the RS, consequently.
5. Strict system of forced regulation of road traffic. Intensity of the increase of traffic flows in the main directions, especially in the conditions of two-way traffic which leads to traffic jams at the intersections and lack of priority of public transport. Such a state of traffic flows inevitably leads to conflict situations, road accidents and, consequently, disruptions in the transportation process.

Factors influencing the reliability of the transportation process due to the influence of the internal environment can be grouped into three groups: structural, production and operational.

Structural factors lead to breakdowns due to the structural features of vehicles. Structural factors are eliminated by the manufacturing plant according to the requirements of the transport companies.

Factors of production are assessed by the level of maintenance, the state of technical readiness as well as the low levels of the qualification system of the service personnel, the collection and processing of statistical data.

RS maintenance, repair and low level of service leads to non-productive failures and downtime.

RS repair and maintenance of services in proper organization will reduce the number of failures.

The staff which is endowed with high knowledge and skills, detects and eliminates malfunctions fairly quickly.

Operating factors assess the level of impact of the conditions under which the population transports within the city. Among them are:

1. The degree of complexity of the route which includes the presence of road slopes and curves with a small radius leading to a decrease in the speed of the RS.
2. The condition of the route. The poor condition of the route, especially in winter, reduces the speed of the RS, increases the waiting time for passengers leading to violations of the time to reach the end line through the public transport.
3. The level of qualification of the driving staff. The low level of quality of the driving staff leads to the violation of the route, the inability to make immediate decisions reducing the indicators of reliability.
4. Level of work organization. It affects the uneven workload of the driving staff, the increase of their fatigue and the occurrence of failures creating preconditions for improper organization of works on the route.
5. Level of work planning of the rolling stock (wrong traffic mode, turning derailment, driver idle at the end point, etc.).
6. The level of organization of dispatch work.

In addition to the main factors that affect disruptions, there are a number of additional factors such as route crossings, railway crossings, long-term road construction and so on.

The reliability of the transportation process in cities is directly related to meeting the transport service needs of the population.

Measures aimed at ensuring the stability of the transportation process by increasing the reliability of urban transportation also serve as a means of improving the quality of urban transportation services provided to the population of the city.

Since the main thing in urban transportation is to provide a work schedule on the route, the reliability of the transportation process can be understood as the probability of organizing transportation on the routes according to the defined itinerary.

The reliability of the transportation process is assessed by the smooth operation of the rolling stock on each route (5). The time spent serving the population during the day is determined by the sum of the time the rolling stock leaves the assembly line.

However, studies have shown that various types of disruptions occur during this period leading to dynamic imbalances (2). These failures require the establishment and implementation of an intra-city Traffic Management Operational System (TMOS).

Taking this into account, there is an urgent need to examine the temporal sequence or frequency of failures the validity of the urban passenger transport UPS as a means of restoring the transportation process.

The reliability of the transport process means the provision of transport services to the population within a certain period of time, maintaining the values specified in the specifications defined by the regulatory documents (timetable, schedule time, etc.) in the appropriate conditions of rolling stock operation [1,2].

In our studies, the definition of the reliability of the transportation process to serve as a working model is very general and it requires certain details. Therefore, when solving the problem, it is advisable to assess the reliability according to the stages of the transportation process (line omission, line work), and then the transportation process as a whole (Fig. 1).

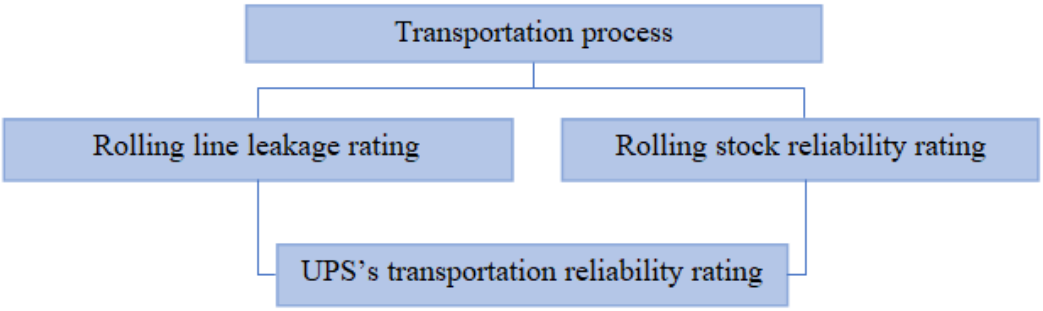

Fig. 1 Reliability of urban transportation process
extended evaluation scheme

The reliability of the transportation process is determined by the probability of working on the line without leaving a fault line in the period from the departure of the urban passenger rolling stock to the return [2].

In this case, it is accepted that each of the stages of the transportation process is the simplest. It is assumed that it can be in only two states: working (passenger transportation provision) disrupted (cessation of transport services to passengers due to the impossibility of carrying out the transportation process).

Therefore, the state of the transport process is determined by the state of the elements that provide it. The failure criterion allows the whole set of states of the stages of the transport process to be divided into two subsets.

The first subset is characterized by the state of dynamic equilibrium of the transport process (functionality of all stages of transport), the second is characterized by the state of dynamic equilibrium of the transport process (disruption of any auxiliary phase) at time t.

The theoretical description of the transportation process can be presented as follows (function) [4].

$$X_i(t)\begin{cases}1, \text{if the i}-\text{th element that provides the transfer process at time is active,}\\ 0, \text{if the i}-\text{th element that provides the transfer at time is in failure}\end{cases}$$

The state of the transport process, which consists of n supporting elements, is characterized by n-number vectors $X = (X_1, X_2, X_3, \dots, X_n)$.

Therefore, the set of elements of the transport process, consisting of 2 ^ n states, can be divided into two subsets: able-bodied states.

Given that the elements are interpreted as "right" and "wrong" logic values corresponding to the Boolean function of set (X) which is a structural function.

$$X\begin{cases}1, \text{if state X, according to the selected criterion,}\\ \text{corresponds to the normal course of the transfer process,}\\ 0, \text{otherwise}\end{cases}$$

The properties of the Boolean function are that if $X = 1$, that is, all X_i, then, $\Phi(1) = 1$, if $X = 0$, that is, all X_i, then $\Phi(0) = 0$.

This property indicates that if all the components of the transportation process are working, then the transportation process is in good condition.

Conclusion

1. During the regulatory period, various types of disruptions occur in the process of urban road transportation which leads to dynamic imbalances and a decrease in the level of reliability of the transportation process.
2. In order to increase the reliability of the urban transportation process, it is necessary to reduce the number of line omissions, work-related failures and their recovery time. The solution to the problem is possible by determining the factors that cause the failure of the transport enterprise.
3. It is advised to assess the reliability of urban transportation according to the stages of the transportation process (line omission, line work), and then develop appropriate methods for evaluating the system of indicators for the whole process.

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ՔԱՂԱՔԱՅԻՆ ՈՒՂԵՎՈՐԱՓՈԽԱԴՐՄԱՆ ԳՈՐԾԸՆԹԱՑԻ ՀՈՒՍԱԼԻՈՒԹՅՈՒՆԸ ԵՎ ԳՆԱՀԱՏՄԱՆ ՑՈՒՑԱՆԻՇՆԵՐԸ

Միրզոյան Ն.Ա., Գրիգորյան Ք.Ա.
Շուշիի տեխնոլոգիական համալսարան

Քաղաքային ուղևորափոխադրման գործընթացում տեղի են ունենում տարբեր տեսակի խափանումներ, որոնք բերում են դինամիկ հավասարակշռության խախտումների և փոխադրման գործընթացի հուսալիության մակարդակի նվազման:

Հուսալիության բարձրացման համար անհրաժեշտ է որոշել այն գործոնները, որոնցով պայմանավորված է տվյալ տրանսպորտային ձեռնարկության պայմաններում խափանումների առաջացումը:

Առաջարկվում է քաղաքային ուղևորափոխադրումներում հուսալիության գնահատումը կատարել ըստ փոխադրման գործընթացի փուլերի (գիծ բաց թողում, գծում աշխատանք), այնուհետև ամբողջ գործընթացի համար, մշակելով ցուցանիշների համակարգի գնահատման համապատասխան մեթոդներ:

Բանալի բառեր. տրանսպորտ, հասարակական, ուղևորատար, գործընթաց, ցուցանիշ, հուսալիություն:

ОЦЕНКА НАДЕЖНОСТИ ПЕРЕВОЗОЧНОГО ПРОЦЕССА ГОРОДСКОГО ПАССАЖИРСКОГО ТРАНСПОРТА

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В процессе работы городского пассажирского транспорта происходят различные виды сбоев, которые приводят к нарушениям динамического баланса и снижению уровня надежности перевозочного процесса.

Для повышения надежности необходимо определить факторы, которыми обусловлено возникновение сбоев в условиях данного транспортного предприятия.

Предлагается оценку надежности городского пассажирского транспорта проводить по этапам перевозочного процесса (выпуск на линию, работа на линии), затем по всему процессу, разрабатывая соответствующие методы оценки системы показателей.

Ключевые слова: транспорт, общественный, пассажирский, процесс, показатель, надежность.

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Submitted by the resolution of coordinating board of scientific journal of BHT on 19.07.2021

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2. Articles should be submitted in English, the font is Times New Roman, abstracts-Armenian- Unicode /GHEA Grapalat/, Russian -Times New Roman, English – Times New Roman. Line spacing – 1,15.
3. The title of the article is given in 11 capital letters **Bold** p.t. on the right top of the page. They are entitled in the sections of **AGRICULTURE, ARCHITECTURE AND CONSTRUCTION, ECONOMICS, INFORMATION AND COMMUNICATION TECHNOLOGIES, MACHINE INDUSTRY AND LOGISTICS, NATURAL SCIENCES, WATER SYSTEMS** for the bulletin.
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17. Formulas are given in **Math Type** program in the middle and are enumerated in brackets to the right.
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1. Էջի ֆորմատը՝ A4, լուսանցքները՝ 18 մմ (աջ, ձախ, վերև, ներքև):
2. Հոդվածի լեզուն՝ անգլերեն, տառատեսակը՝ Times New Roman, ամփոփագրերը՝ հայերեն (Unicode/GHEA Grapalat), ռուսերեն (Times New Roman): Միջտողային հեռավորությունը՝ 1,15:
3. Էջի վերին աջ անկյունում, գլխատառերով, 11 **bold** տառաչափով գրվում է խորագիրը: Տեղեկագրի համար դրանք են՝ **AGRICULTURE, ARCHITECTURE AND CONSTRUCTION, ECONOMICS, INFORMATION AND COMMUNICATION TECHNOLOGIES, MACHINE INDUSTRY AND LOGISTICS, NATURAL SCIENCES, WATER SYSTEMS**.
4. Հաջորդ տողի ձախ անկյունում գրվում է ՀՏԴ-ն (UDC)՝ առնվազն վեց նիշ՝ 11 տառաչափով:
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6. Երկու տող ներքև, աջից, 11 **bold** տառաչափով գրվում է հեղինակի Անունը, ցանկության դեպքում՝ Հայրանվան առաջին տառը, Ազգանունը:
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8. Հաջորդ տողում՝ աջից, 11 տառաչափով գրվում է կազմակերպության հասցեն:
9. Երկու կազմակերպության կողմից հոդվածը ներկայացված լինելու դեպքում, 7-րդ և 8-րդ կետերը, հաջորդ տողից, կրկնվում են:
10. Հաջորդ տողում՝ աջից, 11 տառաչափով գրվում է հեղինակի էլեկտրոնային հասցեն:
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16. Երկու տող ներքև, 12 տառաչափով գրվում է հոդվածի տեքստը, որը պարտադիր պետք է ունենա հետևյալ բաժինները՝ **Introduction**, **Conflict setting**, **Research results**, **Conclusion**: Հոդվածը կարող է ներառել նաև այլ բաժիններ, մասնավորապես՝ **Materials and methods, Experimental procedures, Discussion**, այլ: Բաժինների անվանումները գրվում են 12 **bold** տառաչափով՝ 10 մմ խորքից: Հաջորդ տողից, 10 մմ խորքից, 12 տառաչափով գրվում է բաժնի տեքստը: Յուրաքանչյուր բաժին սկսվում է գրվել նախորդից երկու տող ներքև:
17. Բանաձևերը ներկայացվում են **Math Type** ծրագրով, առանձին տողով, մեջտեղում և համարակալվում են աջ մասում՝ փակագծերի մեջ:

18. Տեքստում կարող են լինել նկարներ, գծապատկերներ, աղյուսակներ: Նկարները և գծապատկերները համարակալվում են «Նկ.» նմուշառմամբ: Դրանց անվանումները գրվում են 11 **bold** տառաչափով՝ մեջտեղում՝ նկարների (գծապատկերների) ներքևում՝ առջևից նշելով «**Նկ.** և նկարի (գծապատկերի) հերթական համարը»: Անվանման տակ՝ մեջտեղում՝ 10 տառաչափով կարող են գրվել համապատասխան բացատրություններ: Աղյուսակները համարակալվում են «աղ.» նմուշառմամբ: Դրանց անվանումները գրվում են 11 **bold** տառաչափով՝ մեջտեղից՝ աղյուսակի վերևում, իսկ անվանման վերևում՝ աջից, 11 **bold** տառաչափով, գրվում է «**Աղյուսակ** և աղյուսակի հերթական համարը»: Աղյուսակի մեջ գրառումներն իրականացվում են 10 տառաչափով (անհրաժեշտության դեպքում՝ 9 տառաչափով):
19. Հոդվածի վերջում, երկու տող ներքև, ներկայացվում է օգտագործված գրականության ցանկը (**References**)՝ համարակալված ըստ հղումների հերթականության: Աղբյուրները բերվում են [..] նմուշառմամբ: Հոդվածների վրա հղումները ներառում են հեղինակ/ներ/ի Ազգանունը, Անվան, Հայրանվան սկզբնատառերը, հոդվածի անվանումը, փակագծերի մեջ հոդվածի հրատարակման տարին: Այնուհետ դրվում է «//» նշանը և գրվում է հանդեսի անվանումը, քաղաքը, հրատարակման համարը, էջերը: Իսկ գրքերի, մենագրությունների դեպքում՝ էջերի ընդհանուր քանակը: Աղբյուրները ներկայացվում են բնօրինակ և անգլերեն թարգմանված տարբերակներով (ներկայացվում է գրականության 2 ցանկ՝ բացառությամբ այն դեպքի, երբ բոլոր հղումները անգլերեն լեզվով հրատարակված նյութերի վրա են):
20. Առանձին էջի վրա տրվում են հոդվածի ամփոփագրերը հայերեն և ռուսերեն լեզուներով: Արտերկրից ներկայացվող հոդվածների ամփոփագրերի թարգմանությունը, անհրաժեշտության դեպքում, իրականացնում է տեղեկագրի խմբագրությունը: Ամփոփագրի հայերեն տարբերակը ներկայացվում է 11, իսկ ռուսերեն տարբերակը՝ 12 տառաչափով: Ամփոփագրին, ներկայացվող լեզվով կցվում են բանալի բառերը:
21. Առանձին էջի վրա բերվում են հեղինակ/ներ/ի մասին տվյալները (պաշտոն, հեռախոս, գիտական աստիճան, գիտական կոչում, էլ. հասցե):
22. Հոդվածները ներկայացվում են info@bulletin.am հասցեով:
23. Անգլերեն տարբերակից բացի, հեղինակը ներկայացնում է նաև հոդվածի հայերեն կամ ռուսերեն տարբերակը (բացառությամբ արտերկրից ներկայացվող հոդվածների): Ամփոփոգրում, վերնագրից հետո բերվում են հեղինակ/ներ/ի Անվան, Հայրանվան սկզբնատառերը և Ազգանուն/ներ/ը:
24. Հոդվածները ստուգվում են գրագողության դեմ:
25. Հեղինակը կրում է գաղտնի տեղեկատվություն հրապարակելու ողջ պատասխանատվությունը:
26. Հոդվածները տպագրության են երաշխավորվում խմբագրական խորհրդի կողմից՝ խմբագրական խորհրդի անդամի երաշխավորությամբ կամ գրախոսման կարծիքի հիման վրա: Կարծիքը պետք է պարունակի եզրակացություն գիտական նորույթի վերաբերյալ:
27. Բացասական եզրակացություն ստացած հոդվածները տեղեկագրում հրատարակման ենթակա չեն:

Утверждено решением Координационного совета журнала ИВТ от 19.07.2021.

ТРЕБОВАНИЯ К ОФОРМЛЕНИЮ СТАТЬИ

1. Формат страницы - А4, поля - 18 мм (справа, слева, сверху, снизу).
2. Язык статьи - английский, шрифт: **Times New Roman**, аннотации: армянский - (**Unicode/GHEA Grapalat**), русский - (**Times New Roman**). Междустрочный интервал - 1,15.
3. В правом верхнем углу страницы, заглавными буквами, шрифтом 11 **bold** пишется рубрика. Для Известий это**: AGRICULTURE, ARCHITECTURE AND CONSTRUCTION, ECONOMICS, INFORMATION AND COMMUNICATION TECHNOLOGIES, MACHINE INDUSTRY AND LOGISTICS, NATURAL SCIENCES, WATER SYSTEMS.**
4. В левом углу следующей строки проставляется индекс УДК (минимум шестизначное число), размер шрифта 11.
5. В середине следующей строки заглавными буквами пишется название статьи, размер шрифта - 14 **bold**.
6. Две строки ниже, справа, шрифтом 11 **bold** пишутся инициалы Имени (при желании - Отчества) и Фамилия автора.
7. На следующей строке, справа, пишется название организации, размер шрифта - 11.
8. На следующей строке, справа, пишется адрес организации, размер шрифта - 11.
9. В случае представления статьи двумя организациями, пункты 7 и 8 повторяются со следующей строки.
10. На следующей строке, справа, пишется адрес электронной почты автора, размер шрифта - 11.
11. На следующей строке, справа, пишется ORCID автора, размер шрифта - 11.
12. На следующей строке, справа пишется название государства, гражданином которого является автор, размер шрифта - 11.
13. Две строки ниже, в том же порядке, пишутся данные других авторов, если они есть.
14. Две строки ниже, пишется аннотация статьи (**Abstract**), размер шрифта - 12. Слово **Abstract** пишется шрифтом 12 **bold**.
15. Две строки ниже, с размером шрифта 12 пишутся ключевые слова (***Key words)***. Слова «***Key words*»** пишутся курсивом (*Italic*), размер шрифта - 12 **bold**.
16. Две строки ниже, с размером шрифта 12, пишется текст статьи, который обязательно должен иметь следующие разделы: **Introduction**, **Conflict setting**, **Research results**, **Conclusion**. Статья может включать и другие разделы, в частности, **Materials and methods, Experimental procedures, Discussion** и т.д. Названия разделов пишутся шрифтом 12 **bold** с отступом 10 мм. Со следующей строки, с отступом 10 мм пишется текст раздела, размер шрифта - 12. Каждый раздел начинается двумя строками ниже предыдущего.
17. Формулы представляются по программе **MathType**, отдельной строкой, посередине и пронумеровываются в правой части, в скобках.
18. В тексте могут быть рисунки, графики и таблицы. Рисунки и графики нумеруются сквозной нумерацией по образцу - "Рис." Их названия пишутся шрифтом 11 **bold** посередине, внизу рисунков (графиков), с указанием спереди **Рис.** и порядкового номера рисунка (графика). Под названием, посередине, могут быть написаны

соответствующие объяснения, размер шрифта - 10. Таблицы нумеруются сквозной нумерацией по образцу - "Таб.". Их названия пишутся шрифтом 11 **bold**, посередине - над таблицей, а над названием - справа, шрифтом 11 **bold** пишется "**Таблица** и порядковый номер таблицы". Записи в таблице производятся размером шрифта 10, (при необходимости - размер шрифта 9).

19. В конце статьи, две строки ниже представляется список использованной литературы (**References**), пронумерованный по последовательности ссылок. Источники приводятся по образцу [..]. Ссылки на статьи включают Фамилию, инициалы Имени и Отчества автора (-ов), название статьи, год издания статьи в скобках. Затем ставится знак "//" и пишется название журнала, город, номер издания, страницы. А в случае книг и монографий - общее количество страниц. Источники представляются в оригинальной версии и в переводе на английский язык (представляются два списка литературы, за исключением случаев, когда все ссылки делаются на материалы, опубликованные на английском языке).
20. На отдельной странице приводятся аннотации статьи на армянском и русском языках. Перевод аннотаций статей, представляемых из-за рубежа, при необходимости осуществляет редакция журнала. Армянский вариант аннотации представляется 11 шрифтом, русский - 12 шрифтом. К аннотации прилагаются ключевые слова на том же языке.
21. На отдельной странице приводятся данные об авторе (-ах): должность, телефон, ученая степень, ученое звание, адрес электронной почты.
22. Статьи представляются по адресу info@bulletin.am.
23. Помимо английской версии, автор также представляет армянский или русский вариант статьи (за исключением статей из-за рубежа). В аннотации после названия статьи приводятся инициалы Имени автора (-ов), Отчества и Фамилия (-ии).
24. Статьи проверяются на плагиат.
25. Автор несет полную ответственность за публикацию конфиденциальной информации.
26. Статья рекомендуется к публикации редакционным советом по рекомендации члена редакционного совета или на основании его рецензии. Рецензия должна содержать заключение о научной новизне.
27. Статьи, получившие отрицательное заключение, не подлежат публикации в журнале.

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