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С О Д Е Р Ж А Н И Е		T A B L E O F C O N T E N T S
ОБЗОРЫ		**REVIEWS**
Соколова Я.В. АЛГОРИТМ СТРУКТУРИРОВАНИЯ КРУПНОГО ИНФРАСТРУКТУРНОГО ПРОЕКТА В ФОРМЕ ГОСУДАРСТВЕННО-ЧАСТНОГО ПАРТНЕРСТВА	**5**	**Sokolova I.V.** THE ALGORITHM OF STRUCTURING A LARGE INFRASTRUCTURE PROJECT IN THE FORM OF PUBLIC-PRIVATE PARTNERSHIP
Скорченко М.Ю. ЗАРУБЕЖНЫЙ ОПЫТ ОРГАНИЗАЦИИ РЕГУЛЯРНОГО КОНТРЕЙЛЕРНОГО СООБЩЕНИЯ	**19**	**Skorchenko M.Yu.** INTERNATIONAL EXPERIENCE IN ORGANISING REGULAR PIGGYBACK SERVICE
ОРИГИНАЛЬНЫЕ СТАТЬИ		**ORIGINAL STUDIES**
Краснов А.С., Зименкова Т.С., Казначеев С.А., АКсенов Н.А. ПРИМЕНЕНИЕ ТЕПЛОВОГО АККУМУЛЯТОРА С ТВЕРДЫМ ТЕПЛОАККУМУЛИРУЮЩИМ МАТЕРИАЛОМ КАК СПОСОБ ОХЛАЖДЕНИЯ ЧАСТИ СИСТЕМЫ ЖИЗНЕОБЕСПЕЧЕНИЯ И ГРУЗОСОХРАНЕНИЯ ВАКУУМНОГО МАГНИТОЛЕВИТАЦИОННОГО ТРАНСПОРТА	**43**	**Krasnov A.S., Zimenkova T.S., Kaznacheev S.A., Aksenov N.A.** APPLICATION OF THERMAL ACCUMULATOR WITH SOLID HEAT ACCUMULATING MATERIAL AS A METHOD OF COOLING OF LIFE SUPPORT AND FREIGHT PROTECTION SYSTEMS FOR VACUUM MAGNETIC LEVITATION TRANSPORT
Беленцов Ю.А., Казанская Л.Ф. НЕРАЗРУШАЮЩИЕ МЕТОДЫ КОНТРОЛЯ КАЧЕСТВА КАК ФАКТОР НАДЕЖНОСТИ БЕТОННЫХ И ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ В ТРАНСПОРТНЫХ СООРУЖЕНИЯХ	**58**	**Belentsov Yu.A., Kazanskaya L.F.** NON-DESTRUCTIVE METHODS OF CONCRETE QUALITY CONTROL AS FACTOR IN RELIABILITY OF CONCRETE AND REINFORCED CONCRETE STRUCTURES IN TRANSPORT FACILITIES
Капустин В.В., Мовчан А.К., Зайцева Е.В., Курячий М.И. АКТИВНО-ИМПУЛЬСНЫЕ ТЕЛЕВИЗИОННЫЕ ИЗМЕРИТЕЛЬНЫЕ СИСТЕМЫ ДЛЯ ОБЕСПЕЧЕНИЯ НАВИГАЦИИ ТРАНСПОРТНЫХ СРЕДСТВ В СЛОЖНЫХ МЕТЕОУСЛОВИЯХ	**68**	**Kapustin V.V., Movchan A.K., Zaytseva E.V., Kuryachiy M.I.** ACTIVE PULSE TELEVISION MEASURING SYSTEMS FOR ENSURING NAVIGATION OF TRANSPORT MEANS IN HEAVY WEATHER CONDITIONS

Ляшенко А.Н. ВЫБОР СХЕМЫ РЕЗЕРВУАРНОГО ПАРКА НЕФТЯНОГО ТЕРМИНАЛА ПО МНОЖЕСТВУ КРИТЕРИЕВ	**84**	**Lyashenko A.N.** SELECTION OF THE OIL TERMINAL RESERVOIR FARM SCHEME BY A SET OF CRITERIA
Грошев Г.М., Кизляк О.П., Котенко А.Г., Сугоровский А.В., Сугоровский Ан.В. РЕГУЛИРОВАНИЕ ПОДВОДА ТРАНЗИТНЫХ И РАЗБОРОЧНЫХ ГРУЗОВЫХ ПОЕЗДОВ К ТЕХНИЧЕСКИМ СТАНЦИЯМ	**94**	**Groshev G.M., Kizlyak O.P., Kotenko A.G., Sugorovsky A.V., Sugorovsky An.V.** REGULATION OF TRANSIT AND REMARSHALLING FREIGHT TRAINS APPROACH TO TRAIN TECHNICAL STATIONS
Шкляев А.В., Пасынкова Ю.С., Сиверцева Е.С., Сакс Н.В. ИСПОЛЬЗОВАНИЕ УСКОРЕННЫХ КОНТЕЙНЕРНЫХ ПОЕЗДОВ КАК СПОСОБ ОПТИМИЗАЦИИ ЭКСПОРТА КАУЧУКА	**105**	**Shklyaev A.V., Pasynkova Yu.S., Sivertseva E.S., Saks N.V.** USE OF EXPRESS CONTAINER TRAINS FOR OPTIMISATION OF RUBBER EXPORT
Горбунова В.С., Пузина Е.Ю. ЭФФЕКТИВНОСТЬ ВНЕДРЕНИЯ СИСТЕМЫ ЭНЕРГЕТИЧЕСКОГО МЕНЕДЖМЕНТА В ПРОМЫШЛЕННЫХ КОМПАНИЯХ РОССИИ	**119**	**Gorbunova V.S., Puzina E.Yu.** EFFICIENCY OF INTRODUCTION OF THE ENERGY MANAGEMENT SYSTEM IN RUSSIAN INDUSTRIAL COMPANIES
Шматченко В.В., Плеханов П.А., Роенков Д.Н., Иванов В.Г. ПОДГОТОВКА СПЕЦИАЛИСТОВ И РАЗРАБОТКА НОРМАТИВНОЙ БАЗЫ ПРОЕКТИРОВАНИЯ МАГНИТОЛЕВИТАЦИОННЫХ ТРАНСПОРТНЫХ СИСТЕМ В РОССИИ	**138**	**Shmatchenko V.V., Plekhanov P.A., Roenkov D.N., Ivanov V.G.** TRAINING OF SPECIALISTS AND DEVELOPMENT OF DESIGN REGULATORY FRAMEWORK FOR RUSSIAN MAGNETIC LEVITATION TRANSPORT SYSTEMS

СОДЕРЖАНИЕ		TABLE OF CONTENTS
ОБЗОРЫ		**REVIEWS**
Соколова Я.В. АЛГОРИТМ СТРУКТУРИРОВАНИЯ КРУПНОГО ИНФРАСТРУКТУРНОГО ПРОЕКТА В ФОРМЕ ГОСУДАРСТВЕННО-ЧАСТНОГО ПАРТНЕРСТВА	**5**	**Sokolova I.V.** THE ALGORITHM OF STRUCTURING A LARGE INFRASTRUCTURE PROJECT IN THE FORM OF PUBLIC-PRIVATE PARTNERSHIP
Скорченко М.Ю. ЗАРУБЕЖНЫЙ ОПЫТ ОРГАНИЗАЦИИ РЕГУЛЯРНОГО КОНТРЕЙЛЕРНОГО СООБЩЕНИЯ	**19**	**Skorchenko M.Yu.** INTERNATIONAL EXPERIENCE IN ORGANISING REGULAR PIGGYBACK SERVICE
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THE ALGORITHM OF STRUCTURING A LARGE INFRASTRUCTURE PROJECT IN THE FORM OF PUBLIC-PRIVATE PARTNERSHIP

Abstract. The Public-Private Partnership (PPP) is one of the most crucial tools for modernisation development of the state management system, a new concept of cooperation between the state and business. Therefore, it is highly significant to develop the scientific approaches to structural arrangement of infrastructure projects in the form of PPP. The first step towards this is the construction of algorithm of this process, which has been made in this paper.

The state is actively participating in the realisation of large infrastructure projects. A new legislative base, which regulates the priority of the infrastructure, is being formed. With the realisation of the planned projects, only a range of transport accessibility problems is solved. Whereas, the issues of development of transit potential of the country, the increase of transport accessibility of various regions, bolstering the mobility of population, etc. remain open.

An ambitious task to create an alternative transport “arteriole” through the Russian Federation territory may be solved by means of the Russian elaborations of the innovative transport technology on the basis of magnetic levitation.

In order to justify the feasibility of such a large project in the form of PPP, the structuring algorithm has been developed, which enables assessing the project at all viewpoints, starting from the moment of the idea of its realisation to the point of its operation, to determine the time costs, and other constituents of the process influencing the project.

The elaboration is based on a dialectical approach to the study of the innovative development, the application of scientific methods of the analysis and synthesis, classification, expert’s assessments, mathematical statistics, the geographical image of the data, which enable ensuring the reliability of the results and the validity of conclusions.

Creating instruments for structuring aims at exploring and expanding mechanisms of cooperation between the state and private business within PPP.

Keywords: algorithm, project structuring, public-private partnership (PPP), concession, transport.

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АЛГОРИТМ СТРУКТУРИРОВАНИЯ КРУПНОГО ИНФРАСТРУКТУРНОГО ПРОЕКТА В ФОРМЕ ГОСУДАРСТВЕННО-ЧАСТНОГО ПАРТНЕРСТВА

Аннотация. Научно-техническое развитие не только повышает комплексную безопасность и устойчивость транспортной системы, но и способно обеспечить решение социально-экономических и оборонных задач Российской Федерации. В статье рассматривается реализация крупного инфраструктурного проекта транзитных транспортных коридоров на основе магнитолевитационной технологии с применением механизмов государственно-частного партнерства (ГЧП). Данная форма взаимоотношений государства и бизнеса не имеет широкого применения в России, поэтому разработка научных подходов к структурированию такого проекта весьма актуальна. Для обоснования эффективности проекта в форме ГЧП автор с помощью законодательных и нормативных документов в области строительства, ГЧП, регулирования государственной политики разработал алгоритм структурирования. Примененные научные методы анализа и синтеза, классификации, экспертных оценок, математической статистики, графического изображения данных позволили обеспечить достоверность и обоснованность выводов.

Ключевые слова: алгоритм, структурирование, проект, государственно-частное партнерство, концессия, транспорт.

Introduction

Public–private partnership in Russia originated in 1980s with privatisation. In 1990s, the commercial use of state-owned property was revived through conversion in to joint-stock companies and later through renting. The 2005 adoption of Federal Law on Concession Agreements (№ 115-FZ of July 21st, 2005) [1] is determined by objective necessity.

Every project under PPP is aimed at liquidating infrastructure gaps, solving tasks of public interest, such as transport, power engineering, social sphere, etc. As a rule, the project consists in construction, reconstruction, technical maintenance and operation of infrastructural facilities by a private investor who fully or partially construction/reconstruction of a facility by virtue of their own or attracted funds. The balance between the own and attracted funds

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is not fixed by any normative acts, and in most cases, it is the finances attracted from financing organisations to prevail in the projects.

The PPP projects cover long-term relations, allocation of risks and responsibilities between the partners.

The public partner (a state body) can partially finance the construction/reconstruction of the facility and fully finance technical maintenance and operation of it.

Allowing for complication and cost intensity of the construction/reconstruction of infrastructure facilities, PPP mechanisms are optimal tool which makes it possible to launch and realise projects.

Setting the Task

The rise of investments in transport, power, social and communal infrastructure by 6−10 % annually can bolster Russia's economy within the next 5−7 years. The analysis of infrastructure budget for the last 5 years showed their dropping tendency approximately by 10 % annually. At the same time, the share of private investments in the development of infrastructure does not even reach 3 % of all the finances [2].

The potential for cooperation between the state and the private sector is immense, and yet, despite colossal reserves, it is hardly used. Over the course of 5−6 years, owing to governmental bodies, financial organisations, business community, the situation began changing drastically. This became also possible owing to active development and application of PPP mechanisms.

It is necessary to popularise and promote PPP tools. One of the options of scientific support of these processes is the development of an algorithm that would specify all phases of structural arrangement of the project.

Apart from modernisation and infrastructure development, the application of PPP mechanisms in Russia can increase efficiency of government-owned property management and growth of income from the government-owned assets. In addition, an obvious advantage of PPP over privatisation policy is the possibility for the state to retain the property right for these facilities.

PPP is one of the most crucial instruments of modernisation development of the state management system, being a new concept of relations between state and business. Therefore, it is highly important to develop the scientific approaches to structural arrangement of infrastructure projects in the form of PPP. The first step towards this is the construction of the algorithm of this process, which has been made in this paper.

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Assumptions

Employing the mechanisms of PPP, the state in the conditions of budget deficit acquires the possibility to realise a project without increasing the debt ratio, reduce expenditures for pre-project planning at the expense of private initiative tools, and attract new competencies during the construction/reconstruction, operation and technical maintenance.

The private partner is given a guarantee that their investments should be returned, which is very important especially in volatile macroeconomic conditions.

Possible forms of realisation of the infrastructure project are given in the fig. 1 [3].

Unlike governmental procurement, when all expenditures for preparation works, construction/reconstruction and operation are fully covered by the budget, in PPP projects the expenditure commitments are distributed in time: the expenditures for preparation activities are distributed among the parties, a significant part of expenditures for construction/reconstruction is born by the private party, the increase of strain on budget takes place only at the stage of operation. As a rule, the budget saving at the stage of construction/reconstruction of an object is higher in total, than overpayment at the stage operation.

The state is actively participating in the realisation of large infrastructure projects. To coordinate this work, on October 15th, 2016, the Government of the Russian Federation issued the Decree № 1050 “Of the Organisation of Project Activities in the Government of the Russian Federation” [4].

By the Order of the Government of the Russian Federation № 793-r of April 26th, 2017 [5], the amendments were adopted, which are subject to inclusion in the List of Large Projects with the government involvement (hereinafter referred to as the List), including the infrastructure projects, which are financed within the Federal Target Programme and by the Russian National Wealth Fund finances, which are subject to monitoring. The List was approved by the Order of the Government of the Russian Federation № 449-r of March 18th, 2016 [6]. According to the amendments, the List encompasses 71 projects, among which there are:

- roads – 24;
- railway transport facilities – 6;
- water transport facilities – 7;
- air transport facilities– 6;
- bridges – 2;
- power engineering – 5;
- medicine – 6;
- science – 3;
- stadiums – 7;
- other items – 5.

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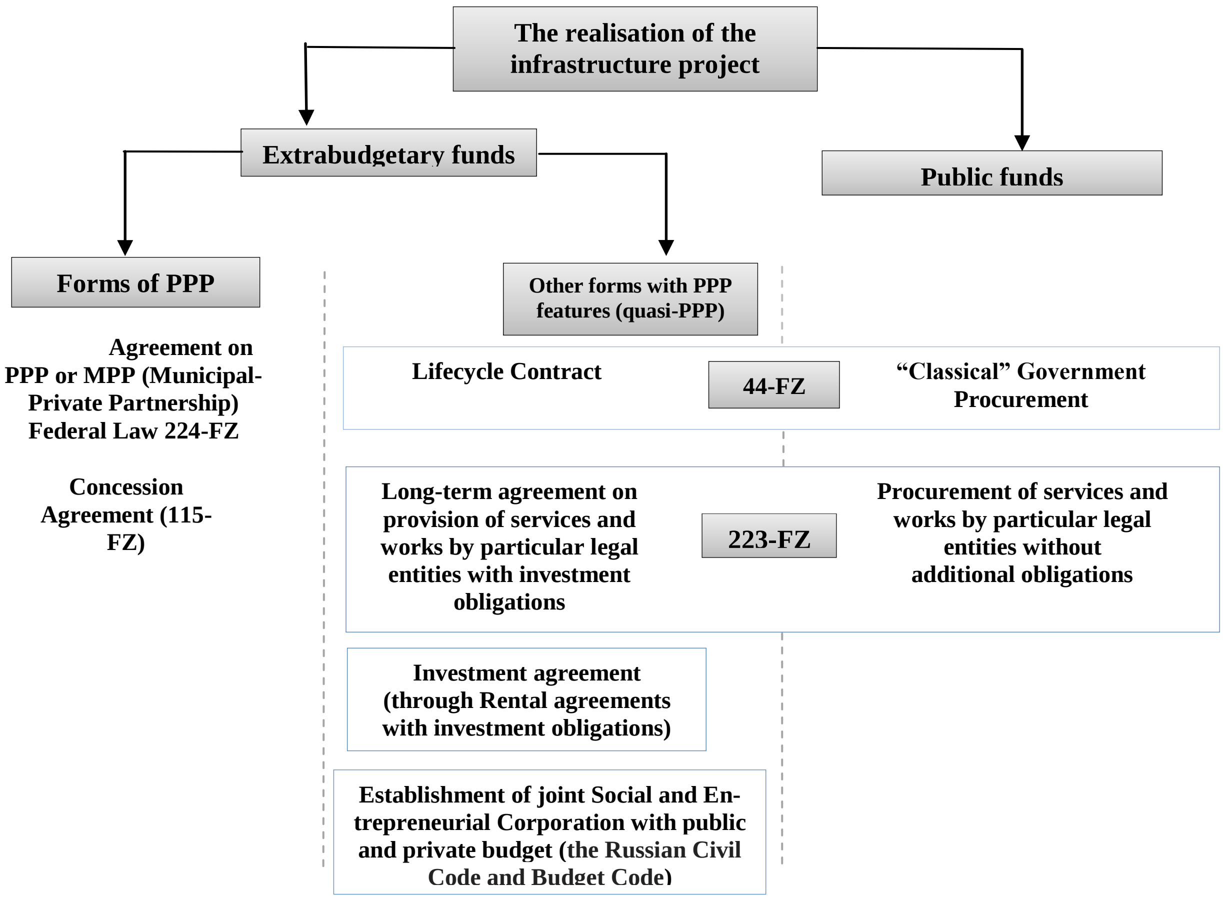

Fig. 1. Possible forms of realisation of the infrastructure project

Forty-five projects on the List relate to the construction of the transport infrastructure objects.

The infrastructure operators at their levels also take efficient steps. For instance, in 2017 the amount of JSC “RZD” investment programme made almost 500 billion rubles [7]. The realisation of the large projects has been prioritised. Among these projects, there are the modernisation and development of the railway infrastructure of the Eastern Polygon, the development of the Moscow transport system, the reconstruction of the section Mezhdurechensk – Taishet, the development and upgrade of the railway infrastructure on the approaches to the Azov and Black basin seaports, etc. [8].

Despite significant efforts of the transport branch to upgrade and strengthen the infrastructure, there is a huge number of bottlenecks, the elimination of which requires cutting-edge technologies and justified forms of the realisation of the projects with the governmental involvement, whose official representatives are eager to develop and drive forward the realisation of the infrastructure projects in terms of long-term partnership [9].

With the realisation of the planned projects, only a range of transport accessibility problems is solved. Whereas, the issues of development of transit potential of the country, the increase of transport accessibility of various regions, bolstering the mobility of population, etc. remain open.

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Magnetic Levitation-based Transport Systems for Intercontinental Transportation

In political, engineering and business circles, an opinion on the necessity of creation of inter-country and intercontinental transit transport corridors (TTC) in the territory of Russia, in the directions of East−West and North-South has been established.

This opinion stands on the results of the processes of the world economy globalisation, which are followed by the circulation of capitals, materials and human resources. The centres of production are rapidly developing in Asia and Southeast Asia – China, India, Indonesia, Malaysia, and Thailand. Hence, the role of transport connections is rapidly growing which are to ensure uninterrupted and timely delivery of raw materials and production to various areas of the world [10].

The Russian Federation is a natural bridge between the East and the West, the North and the South (fig. 2). The Asia-Pacific countries transport approximately 50 millions of tonnes of consumer goods to the EU. If part of this freight traffic is serviced by the Russian transport system, it may become a potential export product for the country. A similar situation is observed with the European countries, the Middle East and North Africa. The existing transport system cannot service even a small share of this product [11]. The transportation by the Trans-Siberian Railway makes only 1 % of the turnover between Asia and Europe [12]. The main advantage of the transportation from China to Europe by railway over sea transport is the speed. However, the commercial speed of train traffic on our railway mainlines is about 16 km/h, which is far lower than that in the USA, Europe and China. Taking this into account, the Chinese Government have approved the New Eurasian Land Bridge for carrying goods bypassing Russia. On January 15th, 2016 the first trial train Ukraine−Georgia− Azerbaijan− Kazakhstan−China departed from the port of Illichivsk (Odessa) [13].

The Transport Strategy of the Russian Federation up to 2030 does not tackle this challenge of time. In the current situation, the following strategic goals of the outrunning model of the development of transport may be formulated:

- to create the East−West and the North−South TTCs, which would by manifold exceed the existing mainlines by virtue of a cutting-edge transport technology;
- to make the private capital the basis for financing the outrunning model of the development model.

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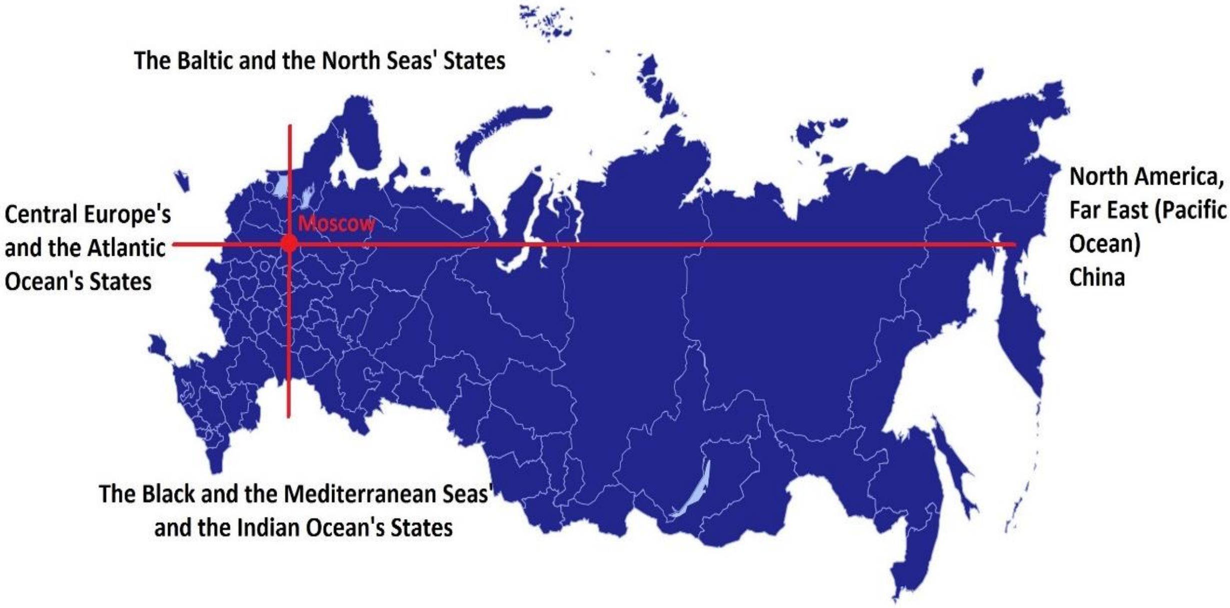

Fig. 2. Maglev transport technology-based TTC in the territory of the Russian Federation

In order to apply the existing legislation to the infrastructure projects within this study, the project of creation of the East–West TTC (hereinafter referred to as the Project) with the application of maglev technology has been considered.

To justify the feasibility of the realisation of such a large Project under PPP, its algorithm of structuring has been developed (fig. 3).

When developing the algorithm, the legislative and normative documents in the field of construction, PPP, and state policy regulation have been used.

The elaboration is based on a dialectical approach to the study of the innovative development, the application of scientific methods of the analysis and synthesis, classification, expert's assessments, mathematical statistics, the geographical image of the data, which enable ensuring the reliability of the results and the validity of conclusions.

The developed enlarged algorithm enables us to consider the Project at all viewpoints, starting from the moment of the idea of its realisation to the point of its operation, to determine the time costs, and other constituents of the process influencing the Project.

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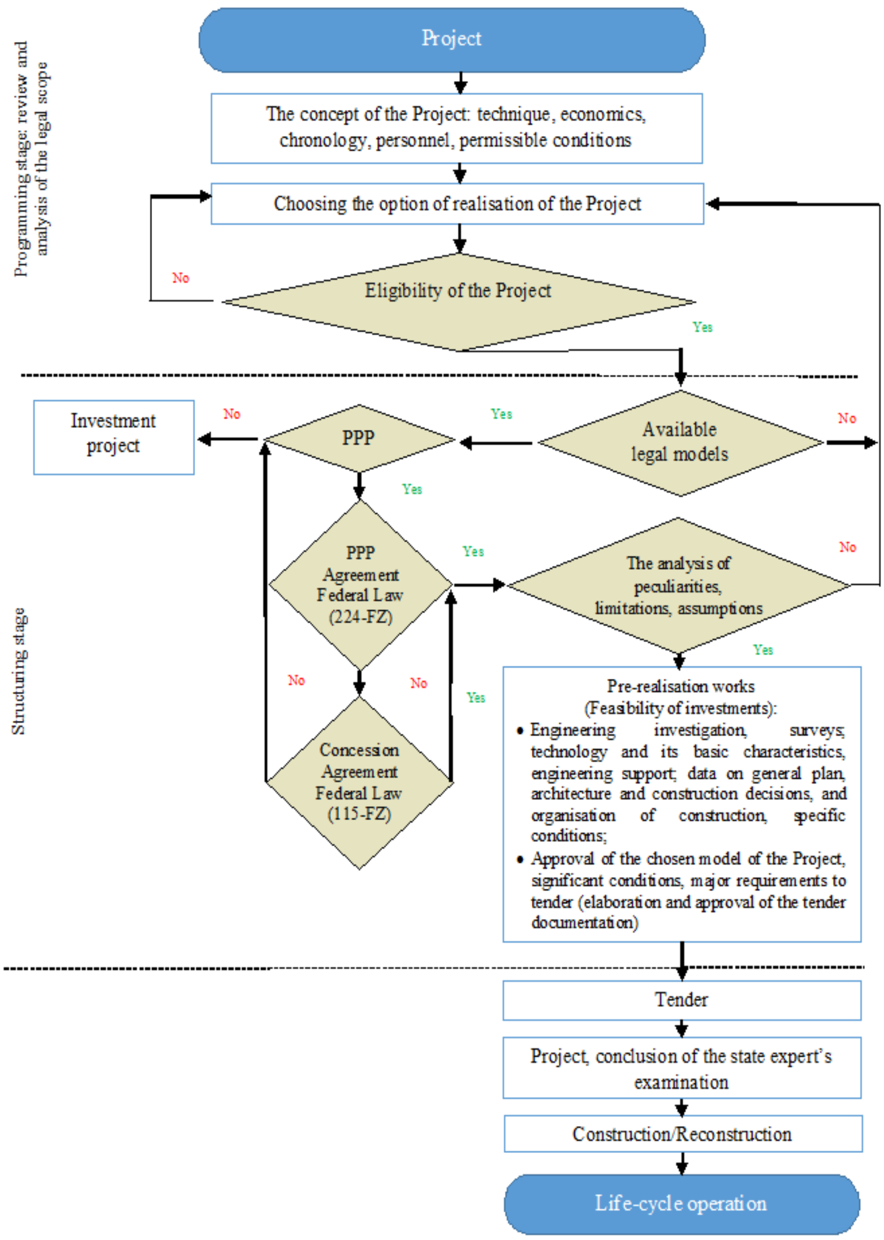

Fig. 3. The algorithm of structuring a large infrastructure project in the form of PPP

The test application of the algorithm to the East–West TTC enabled us to obtain the following results.

The work relating to the creation of the Concept of the Project will take 18 months, provided that an official request is obtained, in order to work out a national scale transport Project, with the interests of the state taken into account. Based on the conclusions of the Concept, a choice will be made to determine the way the Project will be realised. This stage will take approximately 3 months, considering the scope of the Project.

The review and analysis of the legal framework that were conducted enable us to determine the validity of the Project itself and to move on to the legal model of the Project. The PPP form possesses significant advantages over an investment

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project, since the allocation of a land for a linear object is carried out without its being bought by a private partner. Among the available forms of PPP, the concession agreement will be the advantageous. Acting on the basis of concession, the state represented by a large number of regional administrations, in the territory of which the construction of TTC is intended, will entitle the concessionaire to utilise the land to implement new transport technologies. The private partner bears the expense that relate to fulfillment of the obligations within the concession agreement – the creation of TTC with the application of innovative technologies which have been developed by the Russian scientists and specialists.

After working out all peculiarities, limitations and assumptions, the feasibility of investments is carried out. This stage should be carried out in parallel with the development of the legal model of the Project, right after the option of the realisation was chosen. The approximate duration of the stage is two years. Simultaneously with it, the certification of the elements of the system and elaboration of the normative base are conducted.

The stage of tender when dealing with a national scale project may be omitted, as the Project aims at the realisation of the priority vectors of a strategic development of the Russian Federation.

During the course of the next three years, the design will be done in parallel with the development of the initial permissive documentation, then the government experts' review (six months), and the construction (7.5 years).

The ready sections are put into the operation stage by stage, which enables us to start developing the near-by territories and the accompanying infrastructure before the launch of TTC.

The enlarged schedule of the realisation of the Project is given in the fig. 4.

The relevance of this approach is justified by the necessity of applying the accepted succession of actions in design and construction of the objects to the legal norms, with the established practice of the application of PPP mechanisms taken into account.

It is obligatory to develop approaches to structuring and assessing the projects of PPP, considering the best international practices.

The assessment should be made both at the stage of design (programming), with the aim to determine the priority projects and at the possibilities to use them by virtue of PPP mechanisms, and at the stage of structuring the specific project, with the aim to determine and justify the best possible conditions for its realisation.

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Stages of the project	Terms in months														
	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180
The development of the concept of the Project															
Approval of the model of the Project															
Justification of the investments															
Project															
The initial permissive documentation															
The government experts' review															
Certification of the elements of the system															
Construction															
The elaboration of vendor documentation															

Fig. 4. The schedule of the realisation of the Project of the East−West TTC

Undertaking assessments is especially important for large and medium projects, as well as for the projects with direct public financing, full or partial reimbursement of the investor's expenditures at the expense of the budget (projects with availability payments, and minimum revenue guarantee).

At each stage of the assessment (the programming stage and the structuring stage) the similar criteria should be used for assessment of the infrastructure projects:

- social and economic efficiency (at the programming stage – the qualitative assessment and the enlarged quantitative calculation, at the structuring stage – a more detailed quantitative calculation) for the assessment of the feasibility of the project realisation;
- qualitative (expert) criteria of the comparative advantage in order to choose the form of the realisation of the infrastructure project, and to assess the possibility of the application of PPP mechanisms;
- quantitative (calculation) criteria of the comparative advantage in order to determine justification (relevance) of the application PPP mechanism.

The results of the assessment are the integral part of the documents for approval and confirmation of the decision to make up the agreement (the realisation of the project) in the form of PPP [14].

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Conclusion

The large infrastructure projects, especially the transport ones, should be given special attention by the government, as the state of the transport system directly influences the ecological, scientific and technical, economic and military elements of the national security of the state. The technological breakthrough in the development of the Russian Federation's transport system is capable of realising social and economic as well as defense priorities, and significantly increase the transport security level of the state.

The development of the maglev transport technology, as a crucial stage of the transport development, encourages drastic improvement of the technical and economic characteristics of the transport system of our country [15]. The tested Russian elaborations of the innovative transport technology based upon magnetic levitation are capable of solving an ambitious task to create an alternative transport "arteriole" through the Russian Federation territory.

Creating instruments for structuring aims at exploring and expanding mechanisms of cooperation between the state and private capital within PPP.

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INTERNATIONAL EXPERIENCE IN ORGANISING REGULAR PIGGYBACK SERVICE

The economic crisis being overcome by the Russian economy, on the one hand, combined with the inevitable globalisation processes, on the other hand, brings to the forefront the economic efficiency of technical processes associated with environmental safety and the possibility of introduction into the world system. One example of effective use of innovative technologies in the interaction of transport systems in the world is the piggyback transportation.

Aim: The author has conducted the analysis of international experience of the organisation of the piggyback transportation in order to identify technological solutions suitable for efficient use in the Russian market of intermodal transportation.

Methods: To assess the efficiency of different technological systems, the author uses comparative analysis methods, inductive reasoning, system approach method. The author has also synthesised the world experience in the organisation of the piggyback transportation.

Result: The results of the analysis have revealed that the current economic situation in Russia allows the evaluation of innovative transport systems in the first place in terms of the possibility of rapid return, which draws attention to the most economical technologies. In this regard, the use of the rolling highway and Lift-on – Lift-off (Lo-Lo) piggyback systems seems to be the most rational at this stage.

Conclusion: Since 1990s Russia has made a number of attempts to organise regular piggyback service on certain routes. However, due to the lack of demand for this type of services in the Russian market at the moment, investing in the development of piggyback technology involves high risks. The experience of other countries shows that regardless of the chosen technology, stimulating the demand for innovative "green technologies" is not possible without the participation of governmental bodies. At the same time, the creation of the necessary methodological framework for the organisation of piggyback transportation in Russia is possible by virtue studying the multifaceted world practice of piggyback technology operation in the world.

Keywords: transport system, logistic solutions, combined (intermodal) transportation, piggyback, piggyback technology.

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ЗАРУБЕЖНЫЙ ОПЫТ ОРГАНИЗАЦИИ РЕГУЛЯРНОГО КОНТРЕЙЛЕРНОГО СООБЩЕНИЯ

Кризис российской экономики, вписанный в глобализационные процессы, выдвигает на первый план экономическую эффективность технических процессов, сопряженную с экологической безопасностью и с возможностью внедрения в мировую систему. Один из примеров эффективного использования инновационных технологий при взаимодействии транспортных систем в мире – контрейлерные перевозки.

Цель: Проанализировать зарубежный опыт организации контрейлерного сообщения, выявить технологические решения, пригодные для эффективного использования на российском рынке интермодальных перевозок.

Методы: Для оценки эффективности различных технологических систем авторами используются методы сравнительного анализа, индукции, системного подхода. Также обобщен мировой опыт организации контрейлерного сообщения.

Результаты: По результатам анализа выявлено, что современная экономическая ситуация в России позволяет оценивать инновационные транспортные системы, в первую очередь, с точки зрения быстрой экономической окупаемости, обращая внимание на наиболее экономичные технологии. На данном этапе представляется наиболее рациональным использование контрейлерных систем «бегущее шоссе» и Lift-on – Lift-off (Lo-Lo).

Заключение: С 1990-х годов в России на определенных маршрутах пытаются организовать регулярное контрейлерное сообщение, однако в связи с отсутствием спроса на данный вид услуг на российском рынке инвестиции в контрейлерные технологии сопряжены с высокими рисками. Опыт других стран показывает, что независимо от выбранной технологии стимулирование спроса на инновационные «зеленые технологии» невозможно без участия органов государственной власти. Необходимый методологический фундамент организации контрейлерных перевозок на территории России можно создать, изучая мировую практику эксплуатации контрейлерных технологий.

Ключевые слова: транспортная система, логистическое решение, комбинированные (интермодальные) перевозки, контрейлерная перевозка, контрейлерная технология.

Introduction

The economic downturn which is being overcome by Russia’s economy on the one hand, combined with inevitable globalisation processes on the other, brings economic efficiency of technical processes integrated with environmental security and possibility of the implementation into the world system to the forefront.

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From the point of view of the economic efficiency and environmental security, the most efficient way of transporting freight is the seaborne transportation. However, the range of its application is quite limited. In any case, at a certain stage of transportation the application of car transport is expected, since it is the only means of transport with door-to-door service. Railway transport is an efficiently and economically optimal option for carrying freight at large distance or in complicated weather or geographical conditions. However, railway lines in their turn are limited by the possibility to transport freight only between stations. Thus, it is logical to conclude that we should search for an answer to the issue of reducing transport expenses in the relation and transfer of freight between car transport and other means of transport.

Already in XX century in other countries, the innovative systems of combined interrelation of railway and car transport, namely transportation of trailers, semi-trailers and low-loaders by flat wagons, saw rapid development. This type of transportation was named the piggyback transportation.

The USA’s experience in the organisation of piggyback transportation

The father of the piggyback transportation may be considered the USA, where trailers and truck trailers started their operation in the end of 19th century. Despite this, the piggyback transportation services were long distrusted, and only in 1926, an American railway company North Shore Line presented a new service to their clients, that consisted in transportation of truck trailers by railway transport. The technology of loading of that time was quite primitive and consisted in sending the flat wagon to the dead end siding, which was located on the same level, and passing each truck trailer along the entire train up to the anchorage place. At the same time, the tractors were transported with the trailers, which was commercially less profitable than transporting only the truck trailer.

In 1950s on the USA government initiative the unified concept of development of piggyback transportation in the country. The concept was based upon the idea of the organisation of swift delivery of freight for long distances in containers and semi-trailers by trains operating between piggyback-container ports along the country’s entire railway network.

In order to encourage the introduction of piggyback transportation system, the railway companies in the USA were granted legal and economic privileges and exemptions, which would boost development of these services and transfer the load from the overloaded car transport to the railway transport.

The creation of standardised fleet of railway flat wagons in the USA was carried out with the participation of Trailer Train (currently TTX Company), which provides investors with flat wagons. This would facilitate avoiding the empty run on their way back, which was impossible if a client’s platforms were used [1].

In 1960s, to load the truck trailers on the flat wagon, the cranes began to be used, and the model of the first rotating deck for lateral loading with the mechanical rotation of the central part.

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By 1970, more than 1 million truck trailers had been transported on the USA's railways [1].

The modernisation of flat wagons for piggyback transportation continued. In 1970–1980, the 22 900 mm long rolling stock was developed, that could carry two 10700 mm long semi-trailers at one time. The length of the flat wagons did not exceed the length of the passenger wagon, giving no ground for the issue of fitting into the railway curve radius to rise.

In 1980s, as the car's dimensions grew, the 27 100 mm long flat wagons were developed which enabled carrying two 13 700 mm long semi-trailers.

Further increase of the length of the truck exhausted the potential for efficient use of 27 metres long flat wagons. Consequently, the carriers began testing different schemes of loading which enabled them to locate one of the trailers above the coupling of the wagons. Also, during this period a unique solution was elaborated to dismantle the middle part of the deck floor, in order to reduce the tare weight and the axle load.

Today, just like in XX century, in the USA's terminals, as a rule, the standardised equipment is used for transferring truck trailers and high-capacity containers – gantry cranes, reach stackers [2]. This kind of loading and unloading of transport is called Lift-on/lift-off (Lo-Lo), which means performing the loading vertically (fig. 1).

The application of the universal freight handling equipment enables the standardisation of the mixed structure of the freight flow, since cars and containers are transported together. Apart from saving money for construction of the terminal, this technology also accelerates the time for the accumulation of the wagons for dispatch.

Fig. 1. Loading the semi-trailer by the reach stacker

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Besides, owing to absence of electrification on the USA's railways, there is no such issue as the loading gauge. Due to this, the majority of transportation volume there is carried out on standard railway flat wagons. There are even technologies being developed there to transport containers and contrailers piled up on special platforms (fig. 2).

Fig. 2. Double-stack transportation on the platform with the depressed floor on the USA railways

In 1950, in the USA the alternative technology of piggyback transportation was developed – Roadrailer. The point of this technology was to carry trailers without the use of flat wagons, but with the help of the integrated wheelsets, which were lifted up during the highway mode and lowered during the rail one (fig. 3). This system was operated by C&O, Union Pacific и Contrail companies [3]. The main disadvantage of the technology was that apart from high costs of such trailers, equipping them with railway wheelsets would highly contribute to the weight, resulting in decreasing productivity of transportation and limiting the possibility to drive on certain roads.

The terminal of this technology is equipped with rails attached to the parking lot, and with tractors for pulling lorries. Beginning from the end of the train, one by one trailers are attached to the bogie, with the lorries lifting by virtue of their own electric traction. After all the roadrailers are connected together, the bogie is installed in front of the stock which is links the entire system with the locomotive. Since there is no flat wagon, the rolling stock is much lighter than the conventional one. At the destination point, the system is easily disassembled, with the trailers placed in the parking place to be collected by tractor units.

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Fig. 3. Roadrailer bogie system

Today, the roadrailer technology in the USA's railway transportation market is actively used by Triple Crown. The roadrailers are manufactured by a number of companies: Deluxe, Bowser, Santa Fe, Amtrak. Sometimes, groups of roadrailers are connected to passenger and freight trains [3].

The roadrailers can carry 12 % more fright load than conventional piggy-back trains do.

Currently, the piggyback transportation is experiencing the second rise in the USA, which is explained environmentally aware population and toughening up the ecology and noise control norms. Today, the USA's railway transport fleet possesses more than 300 thousand designated flat wagons for operating piggyback. More than 100 national-scale terminals were constructed, where basic transport modes meet and railway lines cross. Also, more than 500 terminals for all modes of transport and several thousands of hubs were erected [4].

Almost all big US railway operators (BNFS, Union Pacific, CSX, Amtrak) offer piggyback transportation services.

Thus, today in the USA all freight for the distance of up to 800 km is transported, as a rule, directly by cars, and over 800 km – by combined on-the-road and over-the-rail transportation [4].

The rolling stock for piggyback operation in the USA is owned both by the state and the shipper. Yet, the most successful experience is considered when the piggyback transportation is forwarded by a car transport enterprise, which is fully responsible for the organisation of the entire cycle of the transportation by road and railway and performs all calculation with railway operators and clients by its own.

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Organisation of piggyback transportation in Europe

It was far later when the piggyback transportation appeared in Europe. The works related to the organisation of piggyback transportation in the western countries began in 1960s. Generally, the development of piggyback transportation was connected with the difficulty for the car transport to cross the natural geographical obstacle − the Alps.

However, the current volume of piggyback transportation of all the railway transportation in the European Union makes approximately 30 % [5]. This situation became possible due to certain pressing conditions, as from the point of view of economic efficiency piggyback transportation does not appear to be an attractive mode of transporting freight. The prerequisites for a widespread use of this type of intermodal transportation in Europe became the following factors:

- complicated geographical and natural conditions (the bulk of piggyback transportation in Europe is concentrated in transport corridors which run on transalpine routes);
- the presence of the unified European piggyback terminals represented by more than 300 terminals in 29 states (initially, the erection of the terminals was supported by the state) [4];
- the presence of special railway tariff for transporting containers;
- legislative limitations for freight transport traffic. For instance, Germany, Austria, France, Italy, Switzerland, Slovakia, Slovenia and the Czech Republic have traffic restrictions for freight transport of more 7,5 tonnes in the daytime during the holidays and the weekend. In Switzerland and Austria – in the nighttime on the permanent basis [4].

The restrictions do not apply to combined freight transport drivers with relatively low road transport involvement.

For instance, after arriving at the terminal station, the trailer hauled by the train, may go to the destination point by itself provided that it is located within a 65 km radius, whereby the above-mentioned restrictions will have no effect on it [5].

Studying the international experience of the organisation of piggyback transportation, one can see several successful, totally different piggyback systems.

Generally, the international technologies of piggyback transportation employ a specially designed rolling stock and relative terminals equipment.

The search for non-standard solutions and the development of innovative technologies for European countries are the forced measure, which can be explained, unlike the USA, by a strict structural clearance of 4300 mm (the European railways are electrified, therefore safe distance to the catenary network should be observed). This limitation causes the platforms with depressed floors or special platforms with a smaller wheel diameter to be used.

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The system of carrying trailer trains and lorries "Rolling highway"

The rolling highway (originally from Austria) is a method of carrying transport units by loading them horizontally on the railway flat wagons with the lowered deck.

In this technology, the trailer train maneuvers onto the flat wagon with the tractor unit on its own. The process of loading is carried out via high ramps. Embarking on and disembarking from the flat wagon is carried out at the rear of the special platform, with the lorries driving along the entire train.

The loading of the rolling highway train consisting of 30 trailer trains takes 30 minutes.

The expense for terminal infrastructure at this method of transportation is minimal. The terminal consists of an even railway track with the length equal to that of the train's, and an endloading ramp. The gaps between the wagons are covered by drop-back shields for unhindered passage of the trailer trains to the end of the rolling stock. Using this shield enables loading another trailer unit between the platforms which makes the entire trailer train longer than the platform (the standard length of the flat wagon by the deck is 13 300 mm).

The rolling highway technology is referred to as the accompanied combined transport. During the transportation (basically conducted in the nighttime in Europe) the lorry drivers travel by the same train in the passenger wagon, to carry on with the door-to-door delivery.

In 1970s, in Europe the special wagons for carrying trailer trains by the rolling highway were developed. One of the Austrian companies developed a platform with a maximum low level of loading surface of 410 mm, which creates the minimum requirements for the height of the transport unit.

In 1980, the German company Talbot developed an improved construction of the wagon with two four-axle bogies. The length of the wagon by its buffers was 19 900 mm with the maximum capacity of 40 tonnes and the wheel diameter of 380 mm.

Currently, the two-axle platforms are widely used, the maximum axle load of which is increased to 22,5 tonnes [6].

In rolling highway transportation, a small diameter of wheels of the platform for carrying trailer trains (a lorry with a semi-trailer) imposes speed limitations on the train traffic and its passing switch yards, and explains an increased wear of the wheelsets (fig. 4).

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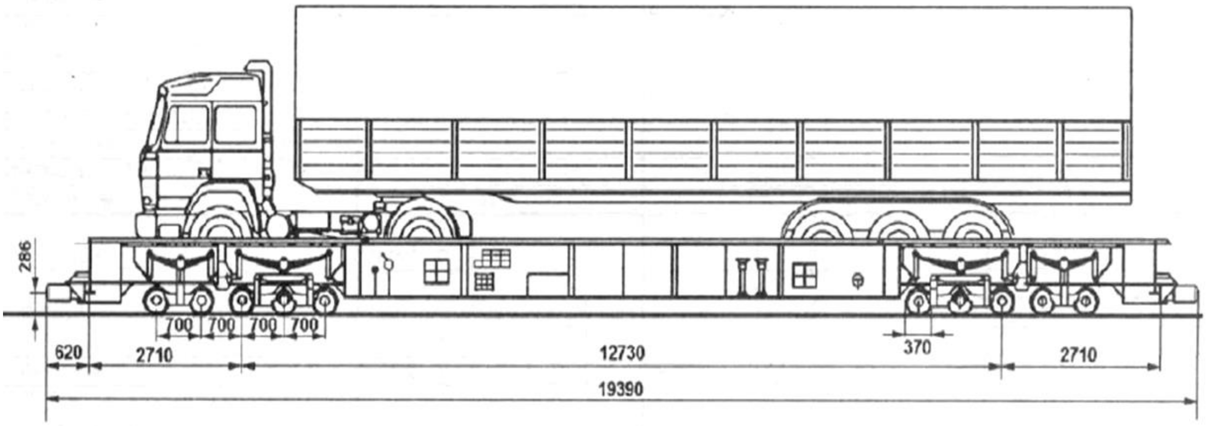

Fig. 4. The scheme of the platform with a small diameter of wheels

The main advantages of the rolling highway technology are:

- the absence of necessity to use cranes;
- maximised simplicity of the organisation of loading and unloading activities;
- minimised volume of investments for buying loading and unloading equipment of the terminal;
- a higher level of safety during loading and unloading works does not require special equipment (apart from weighing equipment), since the terminal is an area for location of the equipment for driving on and off and an external parking area for lorries waiting for loading.

The main disadvantages of the rolling highway technology are:

- a small diameter of wheels of 370 mm which results in limited axle loads (not more than 7 tonnes), increased wear of the wheels due to high rotation frequency (up to 1500 r/min);
- transportation of fully loaded trains only;
- speed limitations to 100 km/h;
- dimension limitations require buying high-tech expensive wagons;
- constant expense for transportation and drivers' wages, irrational use of tractor units;
- the ratio between the gross weight of the transported road train and the net weight of the freight itself.

Piggyback transportation "Modalohr"

A more advanced technology "Modalohr" (France) differs from a conventional rolling highway by the possibility to use standard wheels, which removes the speed limitations and enables cutting operational costs. However, the wagons used in this technology are technically sophisticated and expensive.

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The innovative piggyback technology "Modalohr" developed by the French LOHR Industries, a well-known European manufacturer of transport units. The controlling stake (51 %) is held by SNCF, the National Society of French Railways, and 49 % − by LOHR Industries, which develops and provides technical solutions for carrying passengers and freight. The system was launched in November 2003 between the French Aiton and the Italian Turin.

The "Modalohr" wagon for carrying freight lorries and semi-trailers is designed in accordance with the strict technical regulations, that envisage:

- low floor of the wagon that enables the transport units up to 4 m high to fit into the rolling stock loading gauge;
- the application of standard bogies and wheelsets to keep the cost of the technical maintenance and repairs on the same level;
- horizontal loading and unloading with lateral pockets for simultaneous and swift processing of several lorries;
- simple and reliable mechanical system for coupling and blocking of transport units to ensure safety and low operational costs.

The wagon of the system "Modalohr" has a movable deck which swings 30 degrees and is fixed on the ground level upon arrival at the terminal (fig. 5). The road train then maneuvers on to the platform itself, the trailer is fixed on the platform, the tractor unit is unfastened, the hydraulic mechanism lifts and swings the deck. The platform returns to its initial position.

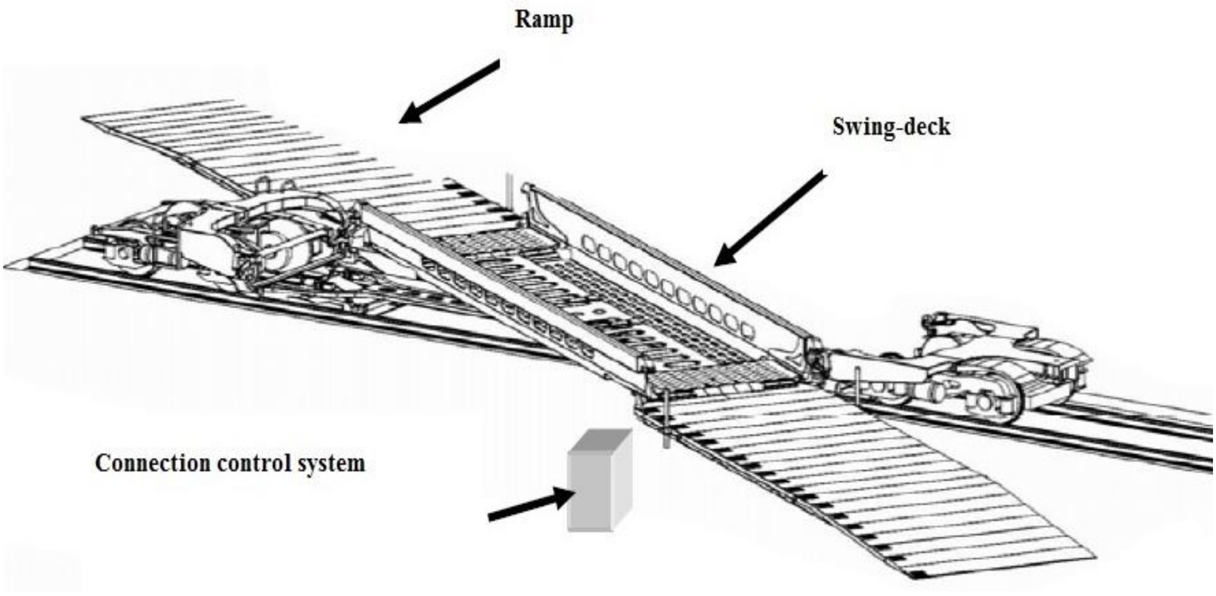

Fig. 5. The Modalohr piggyback platform

The special equipment of the wagon consists of stabilising pneumatic supporters fixed on the bogies and resting on the ground, and of a pneumatic gear whereon the semi-trailer is fixed [7].

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The Modalohr terminal consists of an even area and does not require high costs for equipment (fig. 6). The rails are embedded in the road surface, the ramps ensure loading and unloading of transport from both sides of the track. Before loading and unloading operations, hydraulic opening system drives rollers and jacks which lift the movable deck to the level of the floor of the wagon and swing it.

Fig. 6. The Modalohr system terminal

The only complexity of loading and unloading procedures is to position the train within 30 cm at the terminal.

The tractor unit and the semi-trailer of the road train are transported in an unfastened state due to limitations of radius curves. Their positioning between the bogies is also impossible due to the length limit of the platform. Consequently, the conceptual principle of the system is that each wagon can carry one lorry, one semi-trailer, or two tractor units.

The intermediate flat wagons rest on the same bogie, the end ones in their turn – on two. Thus, a train of *n* wagons has *n* + 1 bogies.

The equipment that secures the loading deck is of special importance. The safety of traffic is ensured by four locks in the platform. They can be unblocked only in the stations during loading and unloading.

The loading cycle of a 750 m train is completed within 45 minutes. The drivers do not participate in the process. The operation is performed by the terminal's personnel. The terminals where drivers can leave their trailers are open 24 hours a day.

Currently, the Modalohr piggyback trains operate on two routes:

- the Alpine rolling highway between the Aiton (Chambry, France) and Orbassano (Turin, Italy) terminals, which runs through the Frejus Rail Tunnel for 175 km;
- the North – South route between the Bettembourg (Luxembourg) and the Le Boulou (Perpignan, France) terminals – more than 1000 km [8].

The Modalohr trains run irrespective of fullness, in accordance to the strict schedules, like the passenger trains do. The alpine line has four trains running at both directions each day. The fullness of trains varies depending upon

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the time: in the morning the train, as a rule, is loaded by half of its volume, in the noon the fullness makes approximately 30%, in the second half of the day – approximately 70%. In the evening the trains run fully loaded [5]. The interest towards this service is dependent upon the season and the traffic situation.

Currently the bulk of the freight transported by this technology is trailers without tractor units (approximately 80 %) [8]. The trucking companies offer their own tractor units in order to load and unload trailers. To carry trailers with tractor units there is a passenger wagon in the train for transporting derivers.

The cost of construction of the specialised terminal makes 3 million euros, the cost of the specialised platform is 355 000 euros [5].

The advantages of the Modalohr technology are:

- the possibility of the rolling stock to carry high-tonnage containers (40 and 45 ft.);
- the possibility of being used both in accompanied and unaccompanied transportations;
- the possibility to perform loading and unloading simultaneously;
- the absence of necessity to employ cranes;
- the possibility to use twin and triple section wagons (fig. 7). The efficiency of this measure is in benefiting from the weight at the expense of employing fewer bogies and expanded loading surface (table).

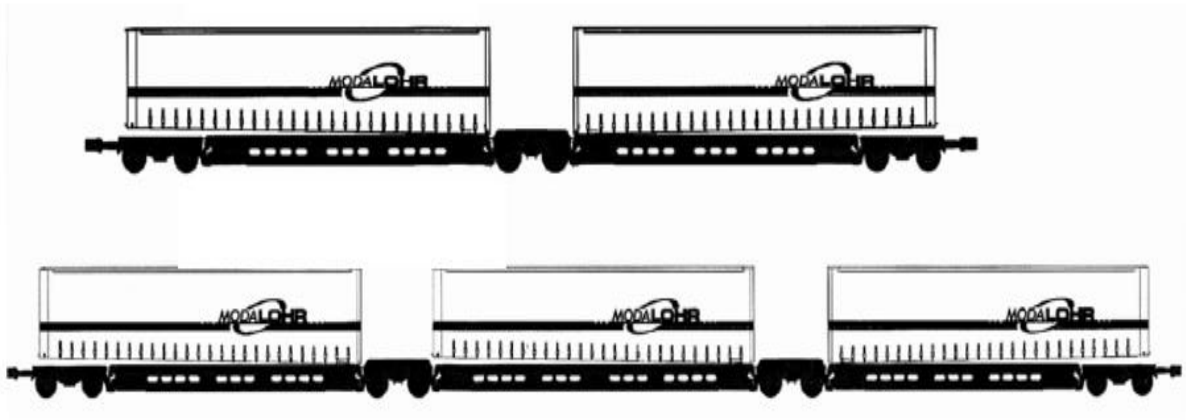

Fig. 7. Variants of twin and triple section wagons train of the Modalohr system

Technical data of twin and triple section wagons

Technical data	Twin section wagon	Triple section wagon
Total length	32,48 m	48,68 m
Weight of the wagon	35,7 tonnes	52,3 tonnes
Maximum speed when fully loaded	120 km/h	120 km/h
Maximum length of the tractor unit with the trailer	16,5 m	16,5 m
Maximum length of the trailer without the cooling unit	13,7 m	13,7 m
Maximum length of the trailer with the cooling unit	14,0 m	14,0 m
Maximum weight of the tractor unit with the trailer	40,0 tonnes	40,0 tonnes
Maximum length of the train (in Europe)	750 m	750 m

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According to this data, the full train carries 26 tractor units with the trailers. Additional increase of capacity is possible if only trailers are transported.

Among the disadvantages of the technology Modalohr there are:
- the necessity of precise positioning of the train at the terminal;
- high-tech processing at the loading area;
- big investments into the rolling stock and the terminals;
- demand in high capacity of the terminals.

Today Modalohr successfully operates in France where there is a number of special terminals and a park of swing-decks.

Piggyback technology "Flexiwaggon"

The Swedish Flexiwaggon is a system of unaccompanied transportation. The owner and the founder of the system is Flexiwaggon AB. The scope of the company includes research and development in the field of design, construction and repair of rolling stock, as well as the provision of logistics services. Flexiwaggon AB puts the environmental friendliness of piggyback transportation as the main advantage over road transport.

This technology does not require erection of terminals for loading and unloading of transport units, and is focused on the application of the specialised platform which enables loading and unloading operations almost in every place.

The special construction of the wagon-platform and the system of its hydraulic jack and the special rotating mechanism ensure rotation of the wagon, thus creating a ramp for the transport to be loaded on to the wagon without any hindrance. The loading and unloading operations can be carried out at any side of the platform, therefore there is no necessity for the train to move backwards during the loading and unloading operations (fig. 8) [9].

Fig. 8. Swing-deck of the system Flexiwaggon

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The entire procedure takes maximum 10 minutes. Besides, the simplicity of the operation of the system enables the drivers to perform loading and unloading without extra personnel, which results in additional savings. The system can carry both the entire road train and the trailer separately.

In addition, a specialised wagon is equipped with a device for connecting the trailer or the car engine to the power supply. Especially this service is in demand in the cold season, as well as for refrigerated trailers. The structural load capacity of the wagon is 50 tonnes, the maximum operating speed is up to 120 km/h.

The European states' authorities pay much attention to ecology and climate change issues, therefore the government of Sweden and the Swedish Energy Agency fully support the project Flexiwaggon. According to the specialists the Swedish Energy Agency, the active application of piggyback transportation may significantly influence the ecologic problem and reduce CO_2 emission in freight transportation by 75 %, and reduce the amount of road traffic, which would positively affect the situation with traffic congestion and the general state of the roads.

The cost of the wagon-platform of the Flexiwaggon system is 175 000 euros [5].

The piggyback technology "Megaswing"

The new technology "Megaswing" is a competitor of "Flexiwaggon" in the Swedish market.

The "Megaswing" technology was developed by one of Northern Europe's premier manufacturer of freight wagons and freight forwarder of the company Kockums Industrie.

The technology means that owing to the special wagon-platform for carrying trailers the loading and unloading operations can take place outside the terminal (fig. 9).

The Megaswing platform is equipped with a sliding mechanism which enables rotation to allow the trailers to be loaded and unloaded (fig. 10) [10].

Special hydraulic supporters pivot and lower the pocket section for the trailer wheels at the angle of the axis of the terminal to ensure that transport unit loads and unloads on its own (fig. 11).

Owing to the depressed floor, the Megaswing can carry semi-trailers of any height, unlike the rolling highway technology.

The loading time is 5 minutes. Considering the simultaneous two-side loading and unloading, the train's standing time does not exceed 30 minutes.

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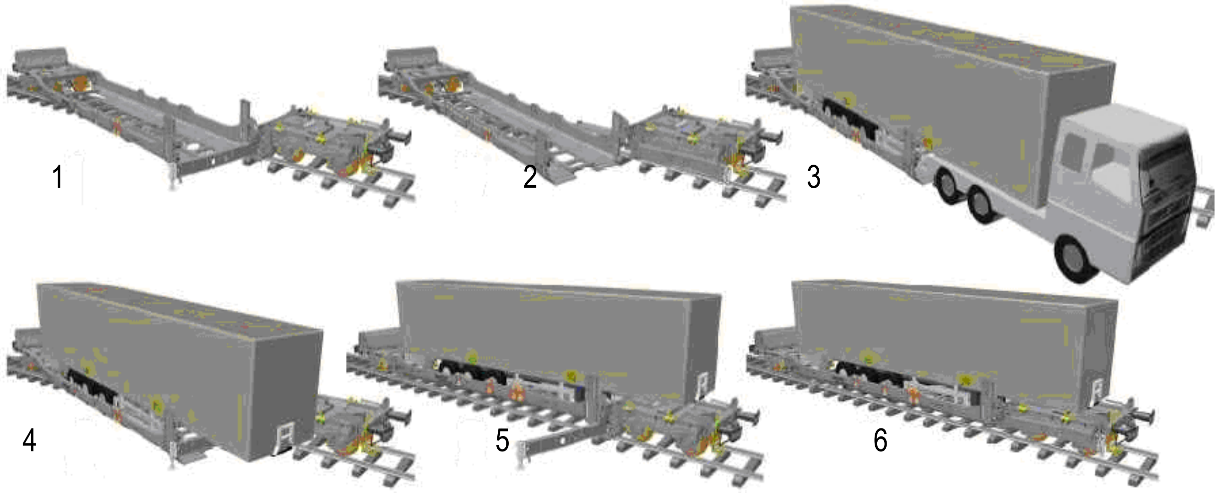

Fig. 9. The scheme of performance of the technology Megaswing

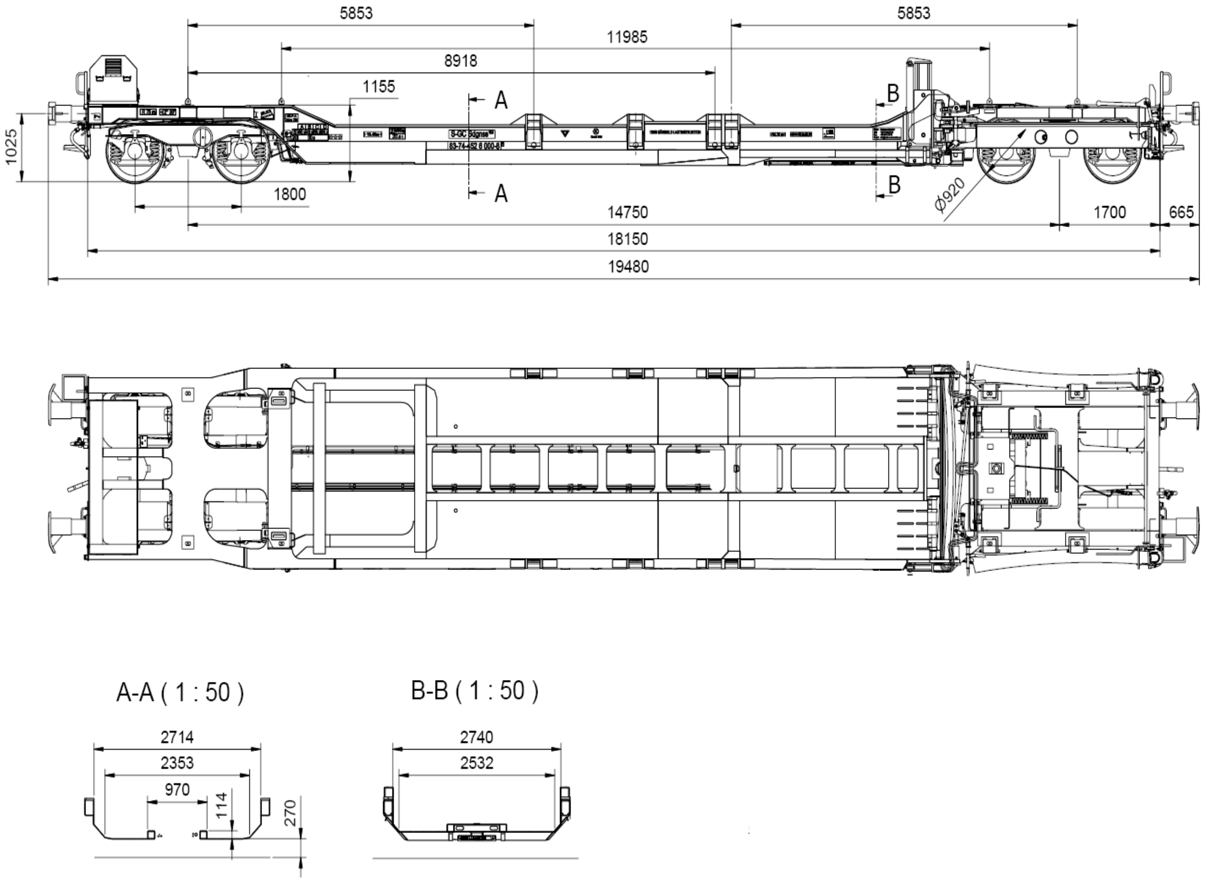

Fig. 10. The scheme of the Megaswing platform

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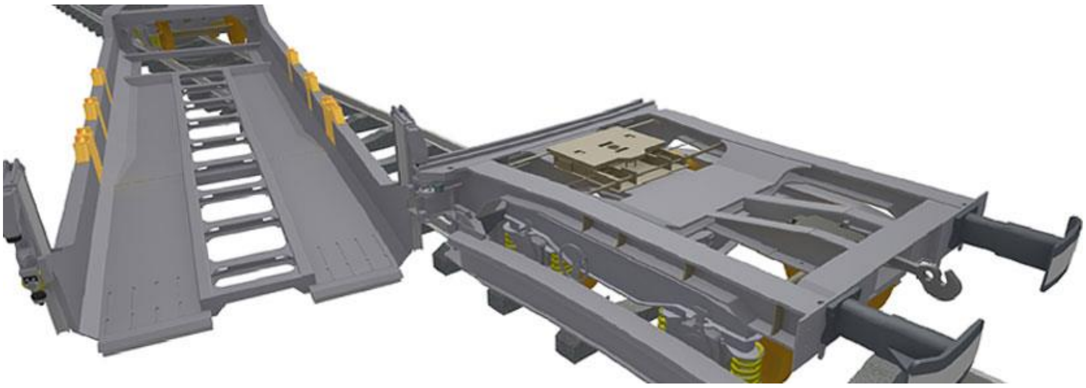

Fig. 11. The profile of the technology Megaswing

The cost of the platform is estimated approximately 270 000 euros.

The main advantages of the technologies "Megaswing" and "Flexiwaggon" are:

- the possibility to carry road trains, semi-trailers and containers on the same platform;
- the speed is up to 120 km/h;
- the application of standard wheels with the diameter of 920 mm;
- the absence of the necessity to construct special terminals, the possibility conduct loading and unloading in own railway warehouse, not at the container terminal;
- simple operation;
- the absence of necessity to position wagons along the loading and unloading area;
- the possibility to swiftly load and unload the entire rolling stock;
- high capacity.

The main disadvantage of these technologies is a high cost of special swing-decks.

The piggyback technology "CargoSpeed"

The system CargoSpeed (Great Britain) fundamentally differs from the earlier mentioned technologies.

The British piggyback system "CargoSpeed" was developed already in the beginning of 1990s under the support of the European Commission for Research and Innovation.

The realisation of this project cost 1,8 million euros.

The work to implement the system "CargoSpeed" was begun in January 2001, with the first ride taking place only in June 2004. The demonstration of the test sample, which was conducted at Barrow Hill, the Centre for Railway Research at the University of Newcastle, Chesterfield, failed. The unsuccessful

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test ride and interruption in the development of the technology gave some advantage to the system Modalohr being developed at that time.

The three basic elements of the system are the specially designed wagon, movable platform and a hydraulic lift (fig. 12).

The technology means that there is a T-shaped hydraulic mechanism between the tracks, which lifts up the platform of the wagon. The mechanism lifts the deck of the platform to the ground level and pivots it so that there is a possibility to conduct loading on it. Thus, the trailer's loading and unloading operations take place.

Specialy designed wagon *T-shaped hydraulic mechanism* *Movable platform*

Fig. 12. Elements of the piggyback system CargoSpeed

The technology allows to make up to 750 thousand handling operations per year. The time of direct loading or unloading of the entire train at a specialised terminal takes from 8 to 30 minutes. As an additional advantage, it should be noted that the system is capable of operating in different directions, that is, taking the trains regardless of the direction of their movement, which increases the operational flexibility of this system.

The cost of erection of the specialised terminal is 2,3 million euros, the price of the CargoSpeed platform is 120 thousand euros.

The advantages of the technology CargoSpeed are:

- relatively low cost of the terminal equipment and specialised platforms;
- the absence of the necessity to employ cranes;

High loading speed.

Among the disadvantages of the technology "CargoSpeed" there are:

- the necessity to erect special terminals;
- the system does not allow transporting the tractor unit and does not envisage carrying a driver;
- complexity of operation due to electronic systems and hydraulic equipment.

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The piggyback system "CargoBeamer"

The German technology "CargoBeamer" also fundamentally differs from other piggyback systems.

This technology was developed in Germany by the company CargoBeamer AG, which works in three main areas: intermodal transportation, design and maintenance of rolling stock, and operation and construction of terminal facilities.

The essence of the technology "CargoBeamer" is that the trailer is placed on a specially designed pallet, which is electrically drawn on the platform along the special guides. In parallel, the arrived trailer is loaded on to the opposite side [11].

The "CargoBeamer" system consists of a reloading terminal where the semi-trailer is removed from the wagon and installed on a wagon pallet, which by means of a transverse shift moves the load onto a specialised railway platform (fig. 13).

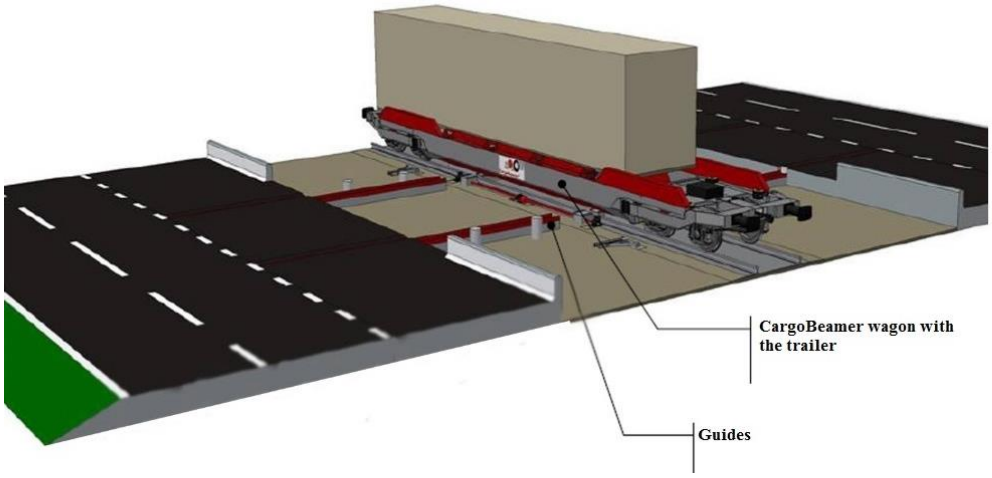

Fig. 13. The loading pallet CargoBeamer

During the loading operation, the tractor unit hauls the trailer on to the special movable pallet, which is located along the rolling stock, and parks it. The trailer is fixed firmly on the pallet, and the tractor unit uncouples and leaves the pallet. Then, the pallet is set on the platform and fixed (fig. 14).

The terminal of this system is equipped with the electronic systems for connection of platforms (fig. 15).

The train with 36 wagons is loaded at the terminal within 15 minutes.

Besides, a large advantage of this system is an automated rail gauge switching from the Standard gauge to the 1520 gauge and back, including in the electrified sections.

The advantages of the technology "CargoBeamer" are:

- the application of standard wheels with the diameter 920 mm;
- the speed is up to 120 km/h;
- the possibility to quickly load and unload the entire train;

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- the possibility to carry road trains, semi-trailers and containers.

Among the disadvantages of the technology there are:

- high cost of the terminal equipment and platforms;
- complexity of operation due to hydraulic equipment, traction mechanisms for platforms, and electronic systems;
- the necessity to position the wagons along the loading and unloading area.

Fig. 14. The technology scheme of the loading
of the trailer on the the CargoBeamer platform

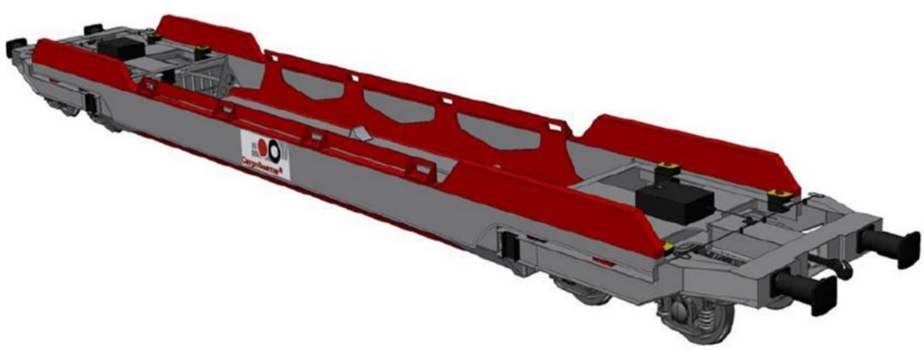

Fig. 15. The CargoBeamer platform

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The system was widely supported by the European Union. Система получила широкую поддержку Европейского союза. Namely, the Project is financed within the programme "Marco Polo − II", one of the points of which is "Efficient Semi-Trailer Transport on Rail Baltica (the project of the standard gauge railway that is intended to connect Eastern Poland, Baltic states and Western Europe)".

Currently, this technology had a few successful test rides from Leipzig (Germany) to Calais (France), where the construction of the second terminal of this technology is underway [11].

The total amount of investment in the French project is 22,5 million euros. The planned processing capacity of the terminal is 800 trailers per day. The terminal will serve two routes: the East – West route from Central to Eastern Europe via Germany, and the North – South route via Italy, Switzerland, Germany and France. Apart from the French port of Calais, CargoBeamer AG has plans to erect 70 terminals, among which there are ones in Polish Legnica, German Hagen, and Lithuanian Mockava.

Final chapter

On the basis of the analysis of different piggyback transportation system one can conclude that the world experience of combining road and railway transport on the basis of the piggyback transportation is very variable. All the mentioned technologies have their advantages and disadvantages. Each of them developed in different countries with different economic, geographic and technological conditions and demands.

The most primitive and the least expensive technologies for processing trailers and road trains are rolling highway and the Lo-Lo systems.

The organisation of test piggyback transportations in Russia was conducted using these technologies only.

In modern Europe, due to the consistently high demand for transportation of transport units by railway, these technologies are not at all competitive. High-tech systems, operating sophisticated specialised equipment, allow making the procedure of loading and unloading the fastest and safest.

However, the Russian conditions dictate that the innovative transport systems should be evaluated from the point of view of the fastest economic return, which results in choosing the most economical technologies. In this respect, using the Lo-Lo and the rolling highway technologies at this stage seem to be the most rational.

Besides, these technologies can be successfully employed on the existing JSC "RZD" infrastructure with the minimum of investment as compared to the specialised systems.

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Since 1990s Russia has made a number of attempts to organise regular piggyback service on certain routes. Basically, the main initiative belonged to JSC “RZD”. However, due to the lack of demand for this type of services in the Russian market at the moment, investing in the development of piggyback technology involves high risks. The experience of other countries shows that regardless of the chosen technology, stimulating the demand for innovative "green technologies" is not possible without the participation of governmental bodies. It also seems obvious, that the development of technological systems of the piggyback transportation should not run chaotically. The geographical and climatic conditions of Russia, without any doubt, require operation of the unified technology in the territory in order to unify the rolling stock and the terminal facilities. In the light of this, the involvement of the Ministry of Transport, the Federal Agency for Railway Transport and other related bodies of legislative and executive power in the process of elaboration of the normative framework and encouragement of demand for the piggyback transportation, becomes unprecedented.

At the same time, the establishment of the necessary methodological framework for the organisation of piggyback transportation in Russia is possible by virtue studying the multifaceted world practice of piggyback technology operation in the world.

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APPLICATION OF THERMAL ACCUMULATOR WITH SOLID HEAT ACCUMULATING MATERIAL AS A METHOD OF COOLING OF LIFE SUPPORT AND FREIGHT PROTECTION SYSTEMS FOR VACUUM MAGNETIC LEVITATION TRANSPORT

Aim: The development of vacuum maglev transport implies solution of an important issue, namely, disposing thermal energy in an air free space. The application of the thermal accumulator (TA) with solid heat accumulating material (SHAM) or melting heat accumulating material (MHAM) as a cooling method for the life support and freight preservation systems (LSaFPS) of vacuum maglev transport is justified by impossibility of thermal energy to be transferred inside the vacuum tube by virtue of convection. Besides, when the accumulators are discharged at the destination points, the saved thermal energy may be used as an additional energy source, thus increasing energy efficiency of the transportation system as a whole.

Methods: In the work given, the authors have used the heat engineering calculation with the application of the similarity theory.

Results: Application of the life support and freight preservation systems (LSaFPS) of vacuum maglev transport will help in solving a problem of removal of excess of thermal energy in the conditions of lack of heat convection and also in increasing energy efficiency of the entire system.

***Keywords*:** vacuum maglev transport, life support and freight preservation system (LSaFPS), solid or melting heat accumulating material, heat removal, disposal of thermal energy, energy efficiency.

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ПРИМЕНЕНИЕ ТЕПЛОВОГО АККУМУЛЯТОРА С ТВЕРДЫМ ТЕПЛОАККУМУЛИРУЮЩИМ МАТЕРИАЛОМ КАК СПОСОБ ОХЛАЖДЕНИЯ ЧАСТИ СИСТЕМЫ ЖИЗНЕОБЕСПЕЧЕНИЯ И ГРУЗОСОХРАНЕНИЯ ВАКУУМНОГО МАГНИТОЛЕВИТАЦИОННОГО ТРАНСПОРТА

Цель: Развитие вакуумного магнитолевитационного транспорта подразумевает решение такого важного вопроса как утилизация тепловой энергии в пространстве с разреженной воздушной средой. Применение теплового аккумулятора с твердым теплоаккумулирующим материалом или плавящимся теплоаккумулирующим материалом как способа охлаждения части системы жизнеобеспечения и грузосохранения (СЖОиГС) вакуумного магнитолевитационного транспорта обусловлено невозможностью передачи тепловой энергии внутри вакуумного трубопровода путем конвекции. Кроме того, при разрядке аккумулятора на пункте прибытия накопленная тепловая энергия может быть полезно использована в качестве вторичного источника тепловой энергии, тем самым повышая энергетическую эффективность системы в целом.

Методы: В данной работе авторы используют методику теплотехнического расчета с применением теории подобия.

Результаты: Применение тепловых аккумуляторов в системах СЖОиГС вакуумного магнитолевитационного транспорта позволит решить задачу отвода избытков тепловой энергии в условиях отсутствия конвективного теплообмена, а также повысить энергетическую эффективность всей системы в целом.

Ключевые слова: вакуумный магнитолевитационный транспорт, система жизнеобеспечения и грузосохранения, твердый аккумулирующий материал, плавящийся теплоаккумулирующий материал, теплоотвод, утилизация тепловой энергии, энергетическая эффективность.

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Introduction

Considering its peculiarities, the life support and freight preservation system of (LSaFPS), namely the ventilation and air conditioning systems of passenger transport units of vacuum maglev transport [1], is one of the most crucial elements which secure comfort and safety of passengers.

The air conditioning system of the transport unit, as well as the thermal balance calculation methodology, is given in detail in [2, 3].

Generally, the on-board air conditioning system in a hermetic vehicle at any atmospheric conditions and for all transportation modes, should maintain the set pressure, temperature, humidity, physical and chemical composition of the air, and the admissible level of noise [4, 5].

The inability to apply the ventilation and air conditioning systems, similar to those deployed on railway transport, is justified by inability to remove the excessive thermal energy outside [6]. In this case, it is relevant to consider autonomous systems for discharging and accumulating the thermal energy.

Setting the tasks

As the main task, the development of methodology, which enables choosing both accumulating substance for removing the excessive thermal energy, and modes of work and processes of charging and discharging thermal accumulators of autonomous on-board LSaFPS [7, 8] in vacuum maglev transport, is considered.

Another task is the development of methodology of heat engineering calculation with the aim to determine air temperature drops, and air conditioning and ventilation monitoring panels, meeting technical requirements.

In order to carry out heat engineering checking calculation of the vehicle with pillowplate heat exchange, the following source data are required:

- cruise velocity V,
- vehicle interior volume $V_{vehicle}$,
- square of the surface under heating S,
- vehicle length $l_{vehicle}$,
- vehicle height $h_{vehicle}$,
- pillowplate height h_{panel},
- pillowplate length l_{panel},
- number of pillowplates n_{panel},
- average air temperature in the vehicle $t_{vehicle}$,
- average temperature of internal walls of the vehicle t_{walls},
- acceptable air temperature drops along the length and height of vehicle $\Delta t_{vehicle\ height}$ and $\Delta t_{vehicle\ length}$,
- acceptable temperature drops of internal wall surface $\Delta_{temp.\ internal}$ in its height,

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- acceptable air speed in vehicle $v_{vehicle}$,
- number of passengers in vehicle,
- thermal, mass and mechanical properties of heat and sound insulation materials,
- alteration of pressure in the vehicle.

The calculation of the pillowplate heat exchange system for cruise velocity mode with possible lowest external air temperature is carried out by virtue of fixed-point iteration. The heat engineering and hydraulic calculation are made for one pillowplate, assuming that the heat exchange and resistance of all plates are equal. The major objective of the heat engineering calculation is to determine air and pillowplate temperature drops with all the above-mentioned technical requirements fulfilled. When calculating the system, operating in mixed mode, the following parameters are sequentially determined – mass airflow through one plate.

The calculation of pillowplate heat exchange system for stable velocity mode of the vehicle with standard parameters of external medium is made in the vacuum tube. The heat engineering and hydraulic calculation is done for one plate, assuming that the heat exchange and resistance of all plates are equal.

The simplified scheme of the interior of the vehicle with air conditioning flows is given in the fig. 1.

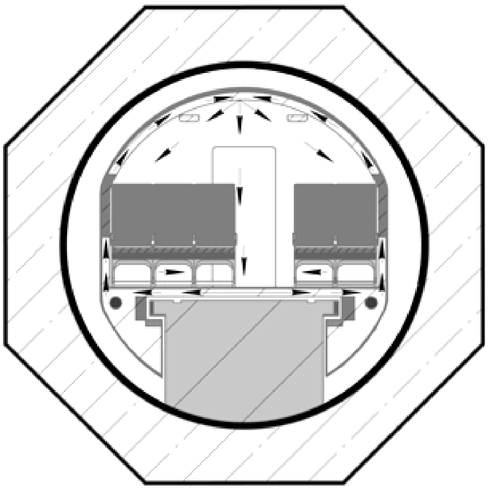

Fig. 1. The simplified scheme of the interior of the vehicle with air conditioning flows

Assumptions

To assess the heat emission of the part of the LSaFPS the following source data are accepted:

$P_{vehicle}$, Pa – pressure of the interior of the vehicle;

$V_{vehicle}$, m^3 – interior volume of the vehicle;

t_{air},^{o}C – entering air temperature.

The mass airflow through one plate:

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$$G_n = \frac{G_{ch}}{nn},\ kg/h,$$

where G_h – amount of air per one hour needed for one plate, determined by conditions of vehicle ventilation:

$$G_{ch} = n \cdot \rho \cdot Vvehicle.$$

The heat transfer coefficient from the plate wall to the air in the vehicle:

$$a(vehicle) = \frac{Nu_{vehicle} \cdot \lambda_{vehicle}}{h}.$$

Amount of heat, transferred from the plate to the interior of the vehicle:

$$Q_{plate1} = k_{plate1} \cdot F_{plate1} \cdot (t_{average\ of\ plate} - t_{vehicle}).$$

Average air velocity in the plate, m/s:

$$v_n = \frac{G_n}{F_n \cdot \rho_{\text{ср}} \cdot 3600}.$$

The Nusselt number [9]:

$$Nu_{plate} = 1{,}02 \cdot \mathrm{Re}^{0{,}38};\ Nu_{plate} = 1{,}128 \cdot \mathrm{Re}^{0{,}7}.$$

Heat balance in the vehicle:

$$Q_1 + Q_1' + Q_{illum} + Q_{plate1} + Q_{floor} + Q_{ceil} = G_h \cdot c_{average} \cdot \Delta t_{int},$$

where Δt_{int} – alteration of the air temperature in the vehicle;

Q_1 – amount of heat, emitted by passengers;

Q_1' – amount of heat from one plate;

Q_{illum} – amount of heat from electric equipment (illumination, generators, accumulators);

Q_{plate1} – amount of heat transferred from the plate to the interior of the vehicle;

Q_{ceil} – amount of heat transferred through the ceiling and lateral walls of the vehicle;

Q_{floor} – amount of heat transferred through the floor of the vehicle.

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Due to the considered mode of transport having almost no convection, the heat transfer from the LSaFPS to the exterior medium is impossible. Consequently, it is relevant to consider thermal accumulators, installed inside the capsules, as the medium for discharging the excessive heat energy.

The general classification of the thermal accumulators [10] is shown in the fig. 2.

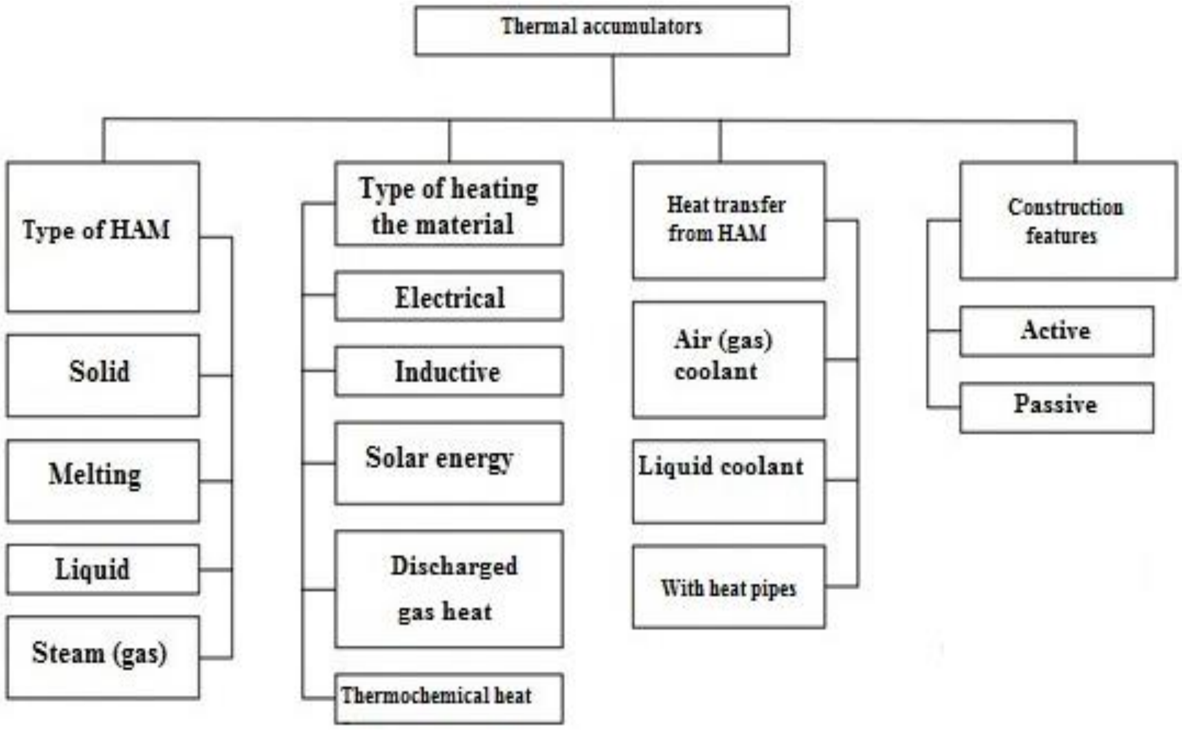

Fig. 2. The classification of the thermal accumulators

Regarding the mode of transport being considered, in order to simplify the structure, the solid body thermal accumulators or accumulation of the energy by means of phase transition heat will be suitable [11]. The application of liquid thermal accumulators leads to necessity in installing additional equipment, which ensures circulation of the coolant.

The accumulation of heat by solid bodies by means of increasing their internal energy. The accumulation medium in this case is a solid body, which is heated and cooled without phase transition. The thermal storage at the same time is defined by internal energy being a constituent of enthalpy.

The accumulation based upon phase transition heat means mainly the accumulation of melting heat, which usually runs with slight volume changes. Sometimes, the solid-liquid phase transition is combined with the solid-solid transition at the temperature which is slightly lower than the melting point. It is frequently suggested to additionally use heating energy (internal energy) of liquid and/or solid phase of the medium.

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Regarding the vacuum maglev transport, it is relevant to consider thermal accumulators with solid heat accumulating material (SHAM) [12], which will simplify the structure and facilitate operation of the LSaFPS of the transport unit.

Materials and Methodology

In this paper, the authors have used the heat engineering calculation method for the thermal accumulator with solid heat accumulating material (SHAM) [13, 14].

When calculating the heat balance, it is important to know the specific values of heat capacity, enthalpy (internal energy), and phase and chemical transformations [15].

The heat transfer by conduction is described by the Fourier's Law, according to which the amount of heat dQ_τ , running in a period of time $d\tau$ through the surface *dF*, normal to the direction of the transfer, equals:

$$dQ_\tau = -\lambda \frac{dt}{dl} dF d\tau,$$

where λ – heat transfer coefficient, W/(m·K);

$\frac{dt}{dl}$ – the thermal gradient, i. e. the alteration of the temperature per unit of length in the direction of heat transfer.

Heat transfer by means of conduction through the wall. The amount of the heat transferred through the flat wall per 1 hour may be defined by the heat equation as the amount of heat passing through a square of infinitely small thickness *dx* inside the wall:

$$\frac{dQ_\tau}{d\tau} = Q = -\lambda \frac{dt}{dx} F.$$

Integrating the alteration of temperature along the entire length of the wall, we obtain:

$$Q = \frac{\lambda}{\delta} F(t_{wall1} - t_{wall2}).$$

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The heat transfer by means of convection. *The convective heat transfer* is the heat transfer by volumes of medium by means of their mutual motion in the direction of the heat transfer. The motion of heat from wall to wall is called the heat transfer. The amount of heat transferred is determined by the Newton law:

$$Q = \alpha F(t_1 - t_{wall}).$$

where α – heat transfer coefficient, W/(m2·K).

The mean temperature difference. In the overwhelming majority of cases, the temperatures of media in the process of heat transfer will change as a result of the running heat transfer and, consequently, the mean temperature will also change (t_1 – t_2) along the surface of the heat transfer. Therefore, the mean temperature difference along the length of the apparatus Δt_{mean}, however, since this change is not linear, the logarithmic temperature difference is calculated.

$$\Delta t_{mean} = \frac{(t_{1'} - t_{2'}) - (t_{1''} - t_{2''})}{\ln \dfrac{t_{1'} - t_{2'}}{t_{1''} - t_{2''}}} = \frac{\Delta t_{'} - \Delta t_{''}}{\ln \dfrac{\Delta t_{'}}{\Delta t_{''}}}.$$

In order to determine the amount of heat transferred by air to the heat accumulating material of the LSaFPS, it is first important to determine the mass of the heat accumulating material (HAM):

$$V_{\text{energy}} = V_{\text{total TESM}} - V_{\text{pipe}}, \text{ m}^3,$$

where $V_{\text{tot HAM}}$ – total volume of the thermal accumulator, m^3;

V_{pipe} – volume of pipes of the coolant and heat receiver, m^3.

The mass of the HAM:

$$m = \rho_{\text{HAM}} \cdot V_{\text{HAM}}, \text{ kg},$$

where ρ_{HAM} – density of the heat accumulating material.

Amount of heat transferred to the HAM:

$$Q = c \cdot m \cdot \Delta t, J.$$

To facilitate calculation of the thermal accumulator, let us conditionally divide the calculation by 2 parts – thermal accumulator charging and thermal accumulator discharging.

The determination of mass flow rate of the coolant in charging operation of the thermal accumulator.

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The mass flow rate of the coolant on the basis of the heat balance equation:

$$Q = G_{air} \cdot \Delta i_{air}.$$

where Δi_{air} – alteration of the enthalpy of the coolant (air), J/kg;

G_{air} – mass flow rate of the coolant (air), kg/s;

Q – amount of heat, transferred to the HAM, J:

$$\Delta i_{air} = C_{air}(t''_{air} - t'_{air}); \quad G_{air} = \frac{Q}{\Delta i_{air}}.$$

The determination of temperature conditions for operation of the thermal accumulator:

$$t_{average\ HAM} = \frac{(t''_{HAM} - t'_{HAM})}{2}; \quad t_{average\ air} = (t_{average\ HAM} - \Delta t_{average});$$

$$\Delta t_{average} = \frac{(t'_{air} - t''_{HAM}) - (t''_{air} - t'_{HAM})}{\mathrm{In}\dfrac{t'_{air} - t''_{\mathrm{HAM}}}{t''_{air} - t'_{\mathrm{HAM}}}}.$$

By means of the obtained values $t_{average\ HAM}$ and $t_{average}$ the required thermal and physical characteristics of the coolants are determined.

The value of the actual velocity of the coolant (air):

$$w_{gas} = G/F \cdot r,$$

where G – volumetric flow rate (air), m^3/s;

F – passage area of the pipe, m^2;

r – internal radius of the pipe, m.

The Reynolds number:

$$Re = w_{flux} \cdot d \cdot \rho_{gas} / M_{gas},$$

where ρ – density of the coolant (air), kg/m^3;

w_{flux} – velocity of flux, m/s;

d – characteristic length of the element of the gas flux, m;

M – coefficient of viscosity of the coolant (air), kg/(m·s).

The value of the heat transfer coefficient is determined from the equation:

$$Nu = \alpha \cdot d / \lambda,$$

where α – heat transfer coefficient, $W/(m^2 \cdot {}^oC)$;

d – characteristic length of the element of the flux, m;

λ – heat conductivity of the medium, $W/(m \cdot {}^oC)$.

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Considering the criterion equation (applicable to air and water):

$$Nu = 0{,}021 \cdot Re^{0,8} \cdot Pr^{0,43} \cdot \lambda_{gas},$$

we obtain

$$\alpha_{gas} = 0{,}021 \cdot \lambda_{gas} / d_{internal\ diameter} \cdot Re^{0,8} \cdot Pr^{0,43} \cdot \Psi_{gas},$$

where Ψ = 1,05 – coefficient taking into account the influence the temperature factor for the air under cooling.

The determination of mass flow of the coolant during charging operation of the accumulator is carried out similarly.

The heat transfer coefficient is determined by the formula:

$$K = 1 / (d_{average} \cdot (1/a_{gas} \cdot d_{internal} + 1/2 \cdot \lambda \cdot ln \cdot d_{external}/d_{internal} + \\ + 1/a \cdot d_{ext}) + R_{poll}),$$

where d_{ext} – external diameter of the pipe;

d_{int} – internal diameter of the pipe;

R_{poll} – thermal resistivity to pollution of the pipe.

When calculating K, it is important to observe the following rules:

if $\alpha_{gas} > \alpha_{air}$ then $d_{average} = d_{ext}$;

if $\alpha_{gas} = \alpha_{air}$ then $d_{average} = (d_{int} + d_{ext}) / 2$;

if $\alpha_{gas} < \alpha_{air}$ then $d_{average} = d_{int}$.

With small thickness ratio of the wall of the pipe $d_{external} / d_{internal} < 1{,}5$ one could use the following relation:

$$K = 1/(1/a_{gas} + \delta_{wall} / \lambda_{wall} + 1/a + R_{poll}).$$

Determination of the duration of full charging:

$$d = E_{accum} / N_{discharging},$$

where E_{accum} – accumulator capacity, kWh;

$N_{discharging}$ – capacity of discharging, kWh.

Results

Regarding the vacuum maglev transport it is relevant to consider the thermal accumulators with SHAM, which will simplify construction and facilitate operation of the LSaFPS of the transport unit.

The fig. 3 shows the enlarged scheme of the operation process of thermal energy accumulator, which not only enables removing heat emissions inside the transport unit, but also utilising this thermal energy.

The fig. 4 shows the scheme of the option № 2 of beneficial use of the thermal energy emitted during discharge of the thermal accumulator. The option

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which predisposes removing thermal energy (Option № 1), differs from the proposed one in including tank cooler in the contour of "cold water".

One of the ways to solve the issue of heat removal in the vacuum tube and prevention of thermal deformations of its structure may become application of melting heat accumulating materials (MHAM), placed in the shell of the vacuum tube. This option may be used as an alternative to heat insulating materials.

Discussion of the Results

The issues considered in this paper, as well as the methods proposed, enable full solving the set tasks. The application of the thermal accumulators as units of autonomous ventilation and air conditioning systems enables not only increase of the level of passengers' comfort, but also a significant reduction of power consumption of these systems. Besides, the issue of environmental safety of this kind of equipment is settled, since they do not use CFCs, required for conventional air conditioning systems.

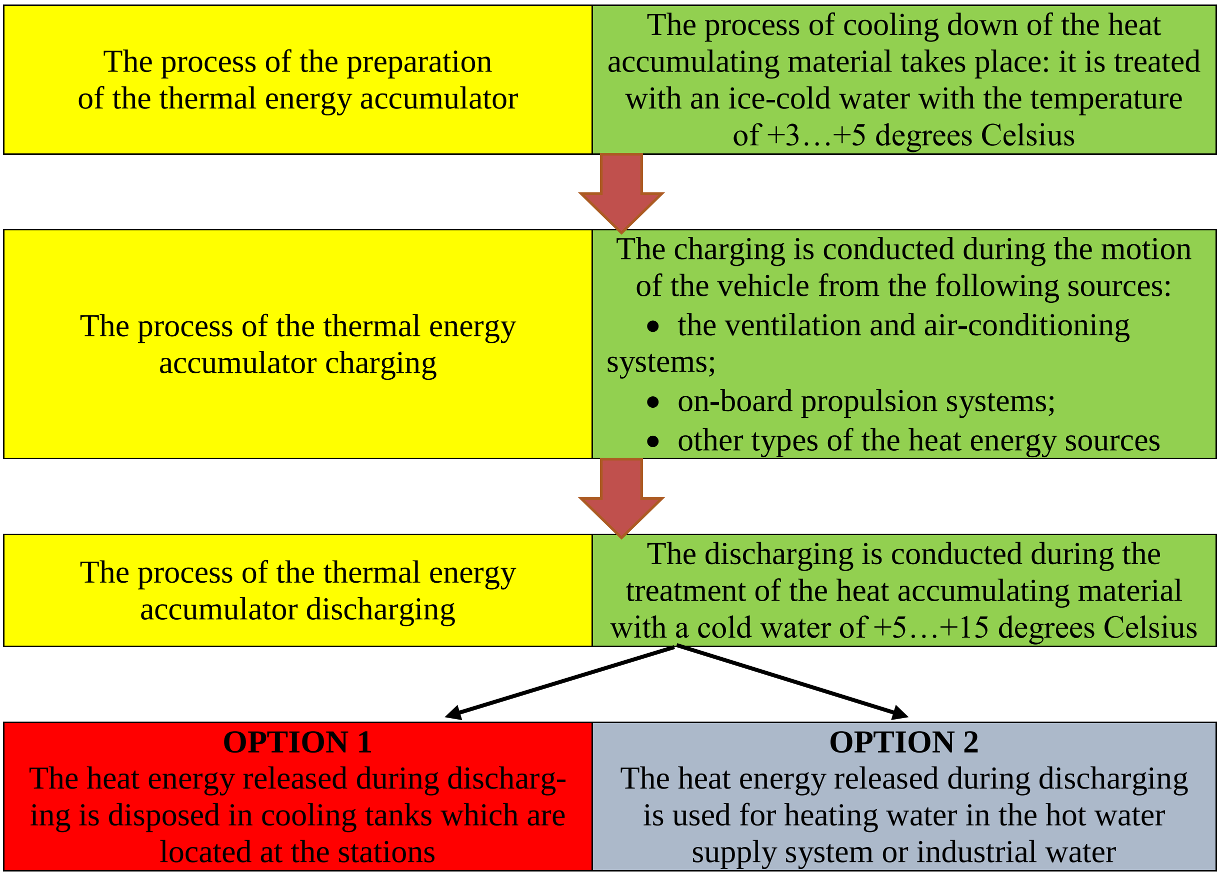

Fig. 3. The enlarged scheme of the operation process of thermal energy accumulator

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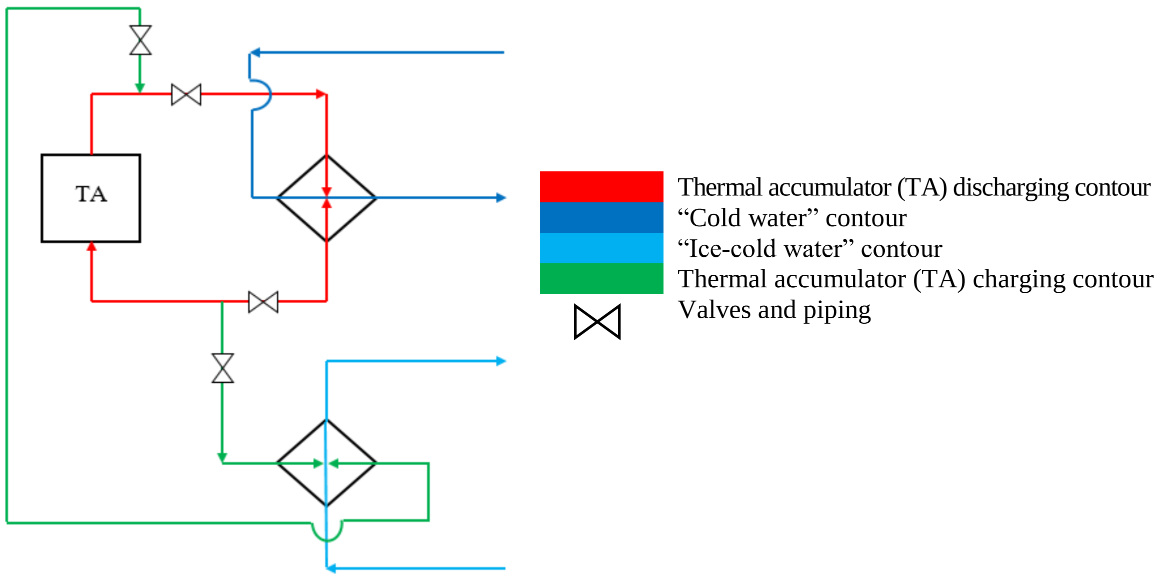

Fig. 4. Principle scheme of beneficial use of the thermal energy emitted during discharge of the thermal accumulator

Conclusion

The proposed system enables proper ensuring the required parameters of microclimate in the passenger or freight transport unit. The paper suggests the method which enables precise choosing both the material of the thermal accumulator and modes of its performance, depending on the operation conditions of the vacuum maglev transport units.

The proposed system has a number of significant advantages, namely:

- the cooling system does not require extra power consumption;
- the problem of heat removal in rarefied air medium;
- the joint application of this system with the stationary charging systems for thermal accumulators will enable increase of energy efficiency of the entire transport systems.

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NON-DESTRUCTIVE METHODS OF CONCRETE QUALITY CONTROL AS FACTOR IN RELIABILITY OF CONCRETE AND REINFORCED CONCRETE STRUCTURES IN TRANSPORT FACILITIES

Aim: The development of theory and practice of construction science leads to a need to enhance the basics of design, construction and operation of concrete and reinforced concrete structures. Despite significant progress, there is risk of collapse of different structures at various stages of their lifecycle. Current state of construction industry leads to a need to increase the quality and reliability of buildings and structures under construction.

Methods: The authors have used methods of probabilistic forecasting in this work

Results: The development of methods of construction materials control, particularly concrete and reinforced concrete, leads to a gradual implementation of non-destructive control methods. To assess the change of confidence and reliability coefficients of designed structures, the authors have substantiated the transition to probabilistic rationing of strength properties of concrete and reinforced concrete structures using classes. Also, the authors suggest implementation of non-destructive control methods. However, non-destructive control methods have a number of drawbacks, the key among these being the decrease of confidence coefficient while preparing a calibration curve, which drastically affects the results of quality control. It is possible to solve the problem by creating a set of control tests including both destructive and non-destructive quality control methods. This will provide systems for collecting testing information of high accuracy.

***Keywords*:** confidence interval, quality control methods, concrete, reinforced concrete, safety factor, reliability.

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НЕРАЗРУШАЮЩИЕ МЕТОДЫ КОНТРОЛЯ КАЧЕСТВА КАК ФАКТОР НАДЕЖНОСТИ БЕТОННЫХ И ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ В ТРАНСПОРТНЫХ СООРУЖЕНИЯХ

Цель: Развитие теории и практики строительной науки позволяет совершенствовать основы проектирования, строительства и эксплуатации бетонных и железобетонных конструкций. Однако есть опасность разрушения конструкций на разных этапах жизненного цикла. Необходимо повышать качество и надежность возводимых зданий и сооружений.

Методы: В данной работе использованы методы вероятностного прогнозирования.

Результаты: Развитие методов контроля качества строительных материалов, в частности бетона и железобетона, постепенно переходит к неразрушающим методам контроля. Для оценки изменения доверительной вероятности и надежности проектируемых конструкций обоснован переход на вероятностное нормирование прочностных свойств бетонных и железобетонных конструкций с использованием классов и предложен переход на неразрушающие методы контроля. Однако неразрушающие методы контроля имеют ряд недостатков, основной из которых – снижение доверительной вероятности при построении градуировочной кривой, что кардинально влияет на результаты контроля качества. Решить эту проблему можно за счет создания комплекса контрольных испытаний, включающих как разрушающие, так и неразрущающие методы контроля качества. Это позволит организовать сбор испытательной информации повышенной точности.

Ключевые слова: доверительный интервал, методы контроля качества, бетон, железобетон, коэффициент запаса, надежность.

Introduction

The development of theory and practice of construction science leads to necessity to improve basics of design, construction and operation of concrete and reinforced concrete structures. Despite significant progress, there is risk of collapse of structures at various stages of their lifecycle. The literature sources based analysis of the quantity of collapses shows that concrete and reinforced

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concrete structures collapse during their operation. In the fig. 1, the common reasons for destruction of concrete structures are shown [1].

At first stage, the reasons for destructions are mistakes in construction, deviation from normative documents and poor quality of reinforced concrete assembly elements, which is connected with lack of quality control, as at the right quality control organisation all mistakes must be duly eliminated. The principled scheme of the quality control triad of the structures erected is given in the fig. 2 [2].

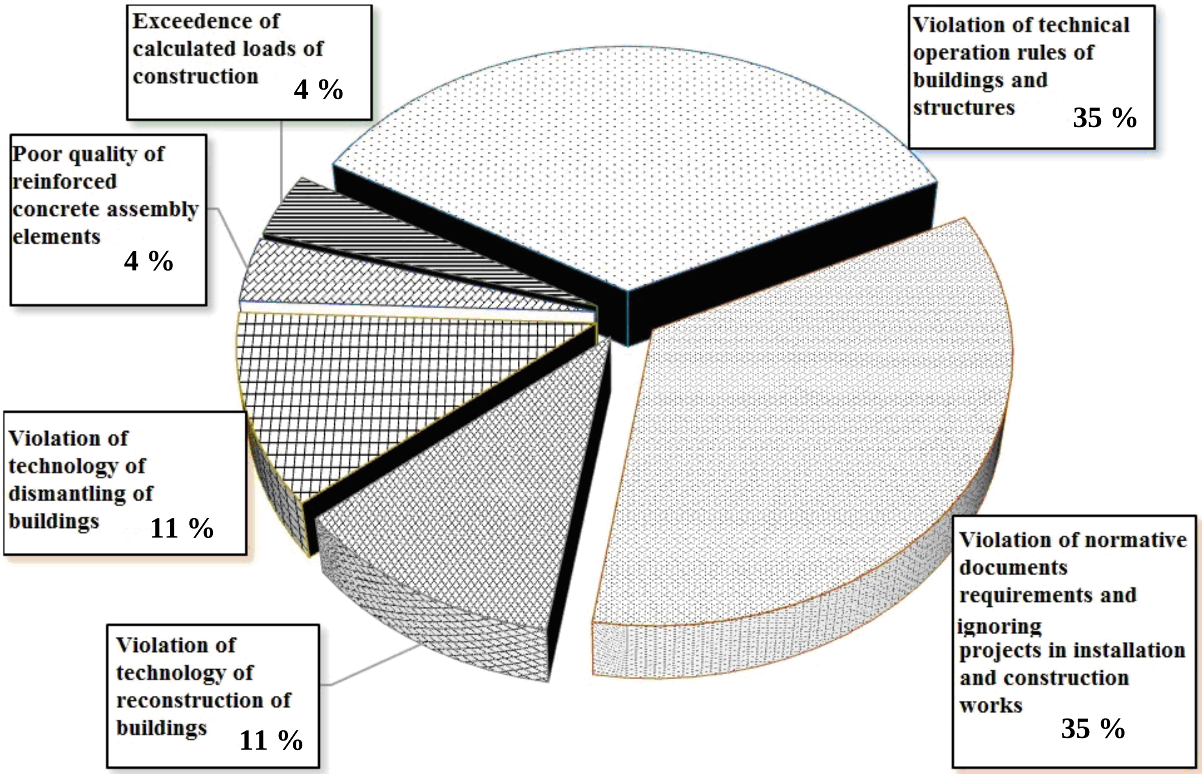

Fig. 1. Reasons for destruction of common types of structures

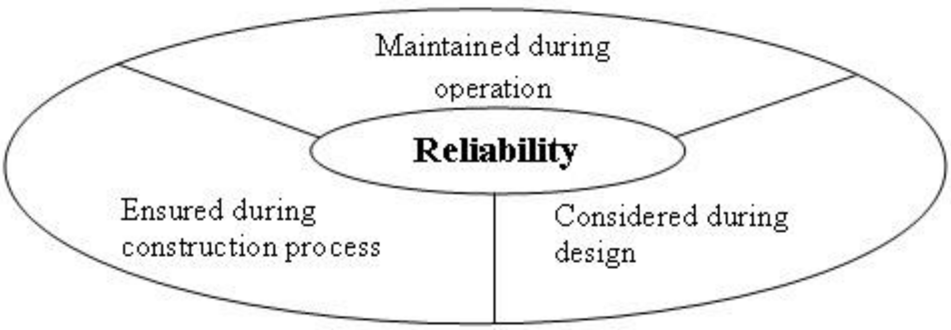

Fig. 2. The principled scheme of the quality control triad of the structures under erection

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Setting the task

To realise this task, one would have to consider joint deformation and crack formation processes in construction materials, which lead to destruction (fig. 3), as well as the real structure of materials, physical and chemical indices and their variability [3].

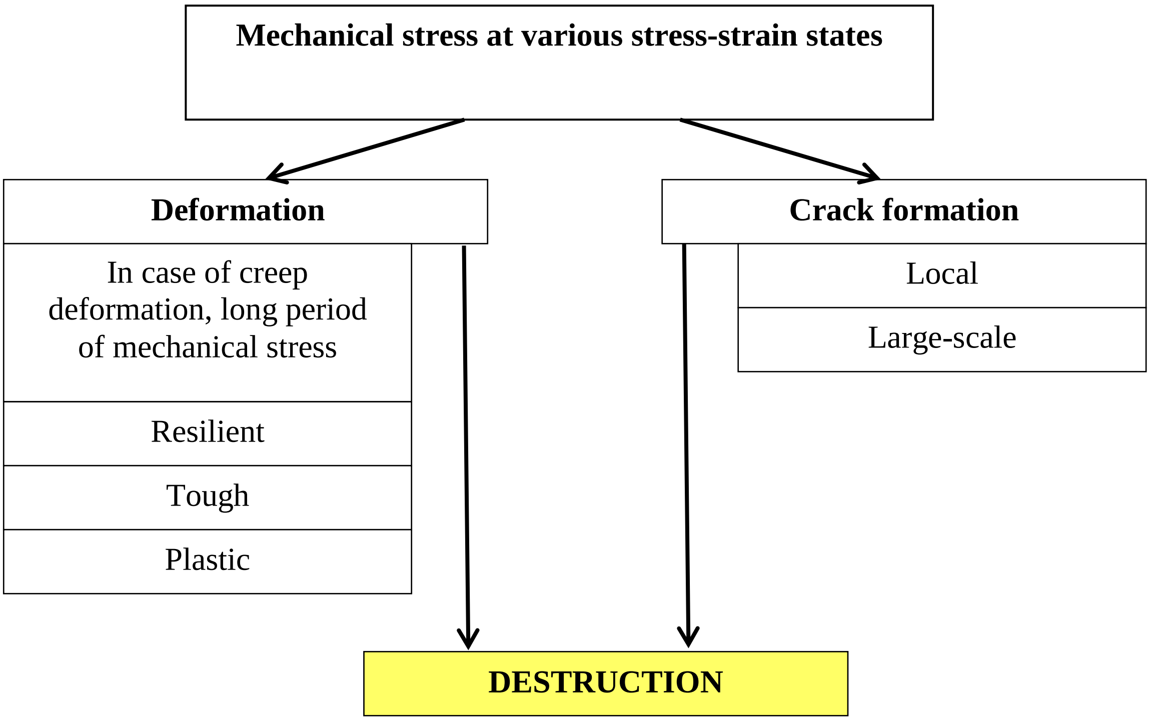

Fig. 3. Scheme of connection between character of deformation and crack formation in composite materials

Assumptions

The destruction of materials takes place due to external impacts, connected with excessive energy: mechanical loads, cyclic freezing and defrosting, chemical reactions and physical processes, etc. After exerting critical amount of energy, the destruction of internal connections of the structural elements of the material. Reliability comprises indices of failure-free operation, durability, repairability, retentivity. One of the defining factors in increase of durability is the principle of mechanical units' control.

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Materials and methods of research

The increase of reliability of structures may be achieved by two ways:

- the first – study of the structure and the properties of materials for enhancing stability of properties with the use of the probabilistic methods and their application in design works and in materials' acceptance test methods;
- the second – increase of quality of inspection and repair systems on the basis of character and speed of crack development in the material under the actual level of load [4].

This results in necessity of improvement of quality control methods, as an important part of ensuring reliability of the buildings and structures erected, primarily in terms of mechanical properties' assessment [5–7]. The development of constructional methods of test and control leads to relevance of substitution of conventional selective destructive control methods of structural behaviour and deformation properties of concrete with all-round non-destructive control. The transition to non-destructive methods allows a substantial effect in terms of quality and labour intensity of control:

- it allows using all-round control, thus detecting defective structures and elements, which cannot be detected by means of selective destructive control methods (e.g. technology violations, improper transportation, gravitational segregation);
- it reduces the time spent for tests and control costs, yet all-round non-destructive control should have influence on reliability of the obtained information.

Let us consider the influence of transition to all-round non-destructive control in erection of concrete and reinforced concrete structures on veracity of the information and reliability of buildings and constructions.

Results

The authors have assessed the influence of the change of confidence of information and reliability on the example of the assessment of concrete grade, which forms a significant amount of safety factor of concrete and reinforced concrete structures. During the assessment, it was assumed that the number of tests was quite significant and was subject to the normal distribution law. The reason for that is quite a large variability of concrete mechanical properties and, primarily, concrete strength. The index of strength is regulated when determining the concrete grade:

$$B = \overline{R}(1 - vt).$$

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For standard and destructive methods, the scheme of test results distribution is given in the fig. 4 (reliability rate is P = 0,95 since the acceptable concrete variability coefficient is 13,5 %, with Student's coefficient making t = 1,64) [8, 9].

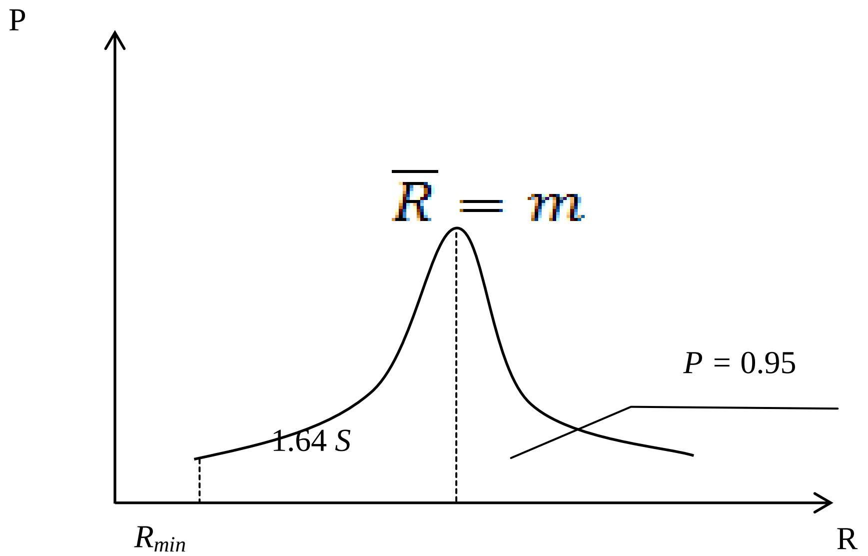

Fig. 4. The relation of basic indices in assessment of strength properties of concrete

Further, the example of application of B30 concrete is given $(\bar{R} = \frac{30}{1-1,64\cdot 0,135} = 36,8\ \text{МПа})$. For a sequence of significant number of B30 concrete samples, the minimum acceptable strength index, considering the acceptable variability coefficient 13.5 %, should make no less than:

$$R_{\min} = \bar{R} - 1,64S = \bar{R} - 1,64\bar{R}v = 36,8(1–1,64 \cdot 0,135) = 30\ \text{МПа}.$$

The variation will make 6.8 MPa whereby the deviation towards the minimum is dangerous for construction and decreases the reliability of structure. With the reduction of strength within acceptable limits, the safety factor of concrete structures also decreases. Practically, on the example of B30 concrete the calculated limit of strength in the first group of limit state will make 17 MPa [8–11].

In normal conditions the calculated safety factor will make S_{factor}= 36,8 / 17 = 2,13. So, on average, the constructions are designed with ample strength which ensures the required level of safety and failure-free operation. Additional-

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ly, reliability is characterised by reliability index and probability of failure-free operation, making [12]:

$$\beta = \frac{\overline{R} - \overline{Q}}{\sqrt{S_R^2 + S_Q^2}},$$

where $\overline{R}, \overline{Q}$ – strength and load effect values;

S_R; S_Q – Squared deviation from the mean (SDM) of strength properties of materials and loads;

The probability of failure is determined by formula [9, 10]

$$P_f = \frac{1}{2} - \Phi(\beta) = \frac{1}{2} - \frac{1}{\sqrt{2\pi}} \int_0^{\beta} \exp\left(-\frac{x^2}{2}\right) dx.$$

The asymptotic formula of probability of failure-free operation is expressed [9]

$$P_f = \frac{1}{\sqrt{2\pi}} \frac{\beta^2 - 1}{\beta^3} \exp\left(\frac{-\beta^2}{2}\right),$$

where $\beta = \frac{S_{factor} - 1}{\sqrt{(\nu_R^2 S_{factor} + \nu_Q^2)}}$;

ν_R, ν_Q – variability coefficient of strength properties of materials and loads.

Discussion of the results

Transition to non-destructive control methods should positively change the situation by means of increasing control points and transitioning to all-round control. In accordance with normative documents, during preparation of calibration curve, the squared deviation from the mean (SDM) is accepted, which equals $S_{НМ}$ = 12 %, except for the separation methods [13]. For separation method with shearing, SDM S = 4 % for 48 mm long anchor and $S_{НМ}$ = 7 % for 20 mm long anchor are accepted [14]. The authors have studied how the additional tolerance of non-destructive methods affects the resulting accuracy of control, hence the reliability of the erected structures with this level of control.

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The increase of SDM leads to reduction of the accuracy of the obtained information, which in its turn leads to enhanced variation of the obtained results of mechanical properties' tests.

To ensure the required confidence interval, one would have to change Student's coefficient, hence to reduce the accuracy of tests. To secure the average strength of concrete, corresponding to the B30 grade of concrete, one would have to reduce Student's coefficient, causing the reduction of confidence probability:

$$tS = t'(S + S_{\text{нм}}),$$

where t и t' – Student's coefficient at the given confidence probability (at standard test $P=0.95$);

S, $S_{\text{нм}}$ – SDM of the standard test during the preparation of calibration curve by means of non-destructive methods.

Then, the results of calculations show that the corresponding coefficient considering SDM will make $t' = 1{,}46$. To secure the strength index with the confidence interval corresponding to the concrete grade, the accuracy of tests makes $P = 0{,}92$, which contradicts the normative documents' requirements [15].

Conclusion

The research carried out shows that transition solely to non-destructive methods should change the approach to determination of acceptable values of mechanical characteristics, considering their guaranteed strength. The existing approach lays decrease of accuracy obtained as a result of the tests from the confidence index $P = 0{,}92$ to 0,95, which in its turn decreases the safety factor, hence the reliability indices of the erected structures. It follows then that it is obligatory to more substantially approach the choice of final inspection of the construction process. The solution to the problem is possible by virtue of establishing a set of control tests, including both destructive and non-destructive methods. This approach will allow creating systems of accumulating high-accuracy test information.

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ACTIVE PULSE TELEVISION MEASURING SYSTEMS FOR ENSURING NAVIGATION OF TRANSPORT MEANS IN HEAVY WEATHER CONDITIONS

This paper presents research results of the Active Vision Area, formed by the Active Pulse Television Measuring System in conditions of decreased transparency of propagation medium.

Aim: To increase backscatter interference suppression efficiency by the Active Pulse Television Measuring System for ensuring navigation of transport means in heavy weather conditions.

Methods: Simulation of Active Vision Area considering light energy attenuation is proportionate to the square of distance and attenuation caused by propagation atmosphere. Performance of experimental researches with the Prototype of Active Pulse Television Measuring System using Big Aerosol Chamber, simulating dense fog and smoke conditions.

Results: The designed model of Active Vision Area allowed estimating the changes of light energy distribution in the observed space layer depending on range of observation and transparency of radiation propagation medium. With equal duration values of the illumination and strobing pulses of the photodetector in conditions of dense fog, significantly big residual backscatter interference was revealed, maximum intensity area of the radiation reflected from objects was displaced from a distance of strobing delay. Illumination pulse duration reduction led to increase of backscatter interference suppression efficiency, improvement of image contrast and increase of accuracy of determination of distance to the observed objects.

Conclusion: The increase of backscatter interference suppression efficiency by the Active Pulse Television Measuring System for ensuring navigation of transport means in heavy weather conditions is a relevant task

Keywords: вackscatter interference, contrast, active vision area, heavy weather conditions, active pulse television measuring system.

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АКТИВНО-ИМПУЛЬСНЫЕ ТЕЛЕВИЗИОННЫЕ ИЗМЕРИТЕЛЬНЫЕ СИСТЕМЫ ДЛЯ ОБЕСПЕЧЕНИЯ НАВИГАЦИИ ТРАНСПОРТНЫХ СРЕДСТВ В СЛОЖНЫХ МЕТЕОУСЛОВИЯХ

Аннотация. Представлены результаты исследования активной зоны ви́дения формируемой активно-импульсной телевизионной измерительной системой в условиях пониженной прозрачности среды распространения.

Цель: Повысить эффективность подавления помехи обратного рассеяния активно-импульсными телевизионными измерительными системами для обеспечения навигации транспортных средств в сложных метеоусловиях.

Методы: Моделирование активной зоны ви́дения с учетом ослабления световой энергии пропорционально квадрату расстояния и затухания, вызванного средой распространения. Экспериментальные исследования макета активно-импульсной телевизионной измерительной системы в большой аэрозольной камере в условиях плотного тумана и дыма.

Результаты: Построенная модель активной зоны ви́дения позволила оценить изменения распределения световой энергии наблюдаемого слоя пространства в зависимости от дальности наблюдения и прозрачности среды распространения излучения. При равной длительности импульсов подсвета и стробирования фотоприемного устройства в условиях плотного тумана выявлена большая остаточная помеха обратного рассеяния, область максимальной интенсивности отраженного от объектов излучения сместилась от дистанции, соответствующей задержке стробирования. Сокращение длительности импульса подсвета привело к увеличению эффективности подавления помехи обратного рассеяния, к улучшению контраста изображения и к повышению точности определения расстояния до наблюдаемых объектов.

Выводы: Применение результатов исследования позволяет повысить эффективность подавления помехи обратного рассеяния активно-импульсными телевизионными измерительными системами в сложных метеоусловиях для обеспечения навигации транспортных средств.

***Ключевые слова*:** помеха обратного рассеяния, контраст, активная зона ви́дения, сложные метеоусловия, активно-импульсная телевизионная измерительная система.

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Introduction

Currently, in modern science and technology, there is a growing dissemination of technical vision systems which are able to efficiently perform tasks of searching and detecting the objects observed in rough weather conditions (fog, haze, dust, snowfall).

The operational range and possibility of detection of the objects by means of conventional television systems are seriously limited in the conditions of low transparency of the propagation atmosphere. The basic reason for limitation of detection and identification ranges in rough vision conditions is the impact of backscatter interference [1].

Backscatter interference occurs due to light photons' scattering on the atmosphere aerosols in the direction of the observer, which leads to significant decrease of the image contrast and, consequently, to impossibility of detecting and identifying the objects of observation [2].

There is quite a broad spectrum of monitoring systems for work in the complicated visibility conditions:

- passive and active-passive low light television systems;
- active pulse television measuring systems (AP TMS);
- thermal vision systems.

AP TMS efficiently eliminates the backscatter interference and is not sensitive to low temperatures unlike thermal vision systems. The working principle of AP TMS is based upon space pulse illumination and time strobing of the photodetector which is equipped with fast shutter.

The essence of the method is brought to the following. The object of observation is illuminated by light pulses, duration of which is significantly shorter than the light probation time to the object and back. In the case when time delay between pulse emission moment and shutter opening moment is equal to double time necessary for the light to cover the distance to the object and back, the observer will be able to see only the object itself and the area of space surrounding it. The depth of this space is determined by both the time of opening state of the shutter and the duration of the light pulse [3].

As a photodetector in the active pulse television measuring systems, as a rule, the image intensifier tube is used, which operates in the pulse mode. The image intensifier tube in the active pulse television measuring systems functions as a fast-acting electronic shutter and image brightness enhancer. To receive video signal, the image intensifier tube is synchronised with video camera.

The synchronisation is feasible by means of joining through fiber-optic element (focon), direct joining of image intensifier tube to light-sensitive element of the television camera or with the use of the relay coupling lens.

The use of the relay coupling lens is justified by the emergence of heavy interferences in the energetics of the carried optical image. The synchronisation by means of joining through focon or direct joining of image intensifier tube to

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light-sensitive element of the television camera causes impossibility of quick change of the device components (non-module construction) and increase of its costs [4, 5].

As the illuminator for AP TMS, the laser-based or LED-based lighter is used, which works in the pulse mode. The duration of the illumination pulses may reach tens or units of nanoseconds, enabling reaching a high pulse power, with the photodetector's short exposure time significantly decreasing background light sensitivity of the system [6].

Depending on the purpose, AP TMS may be used in air, ground, underground, surface and underwater conditions.

The increase of the range of AP TMS is possible both by means of increase of power of the illumination and decrease of the number of radiation angles and acceptance angles.

The most grounded decision, when dealing with significant illumination power, is the scheme of group module of the lighter. The lighter made according to this scheme consists of a range of standard modules with optical axes parallel to each other.

Each module has an objective and an emitter having a laser diode matrix with or without integrator. The radiation of all the modules is focused in one radiation angle, equal to the radiation angle of one module. This scheme of the lighter ensures its minimal longitudinal dimensions and simple radiation forming scheme. The scheme is also convenient with its high repairability, as in case of failure of one module, it can easily be replaced with another one [7].

Depending upon changes of weather conditions, different working modes of the active pulse television measuring systems are used: uninterrupted, active uninterrupted or active pulse mode with the time selection of radiation pulse reflected by the objects.

In the active pulse mode, the control of the AP TMS observation range is carried out by virtue of changing the delay of opening the shutter of the photodetector relative to the illumination pulse (strobing delay). The strobing delay control in the image intensifier tube enables receiving information about the distance to the observed object with a certain tolerance which depends upon the depth and the form of the active vision area.

The strobing delay control of the image intensifier tube in the AP TMS may be realised both manually and semi-automatically, with the use of programmable logic.

When operating manually, the strobing pulse delay, preliminary set for a certain value, is manually gradually and continuously, or discretely and incrementally, increased or decreased to the value corresponding to the maximum or the minimal performance range of the AP TMS. When changing the delay, the zone of the observation is continuously or discretely shifted in range and is combined with the object of interest by the operator. This mode of operation re-

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quires constant involvement of the operator and is not efficient when dealing with fast-moving objects.

When operating semi-automatically, the strobing pulse delay is periodically changed, the scanning of the zone of observation from the minimal to the maximum performance zone is carried out, and detection of the object down the depth of visibility takes place. This mode does not require constant involvement of the operator and can be used when dealing with fast-moving objects.

The AP TMS active vision area

The form of the active vision area will represent the result of convolution of the illumination pulse S_L and the strobing pulse of the image intensifier tube S_g. If the pulses are of the rectangular form and have equal duration, their active vision area will have the form of triangle (fig. 1).

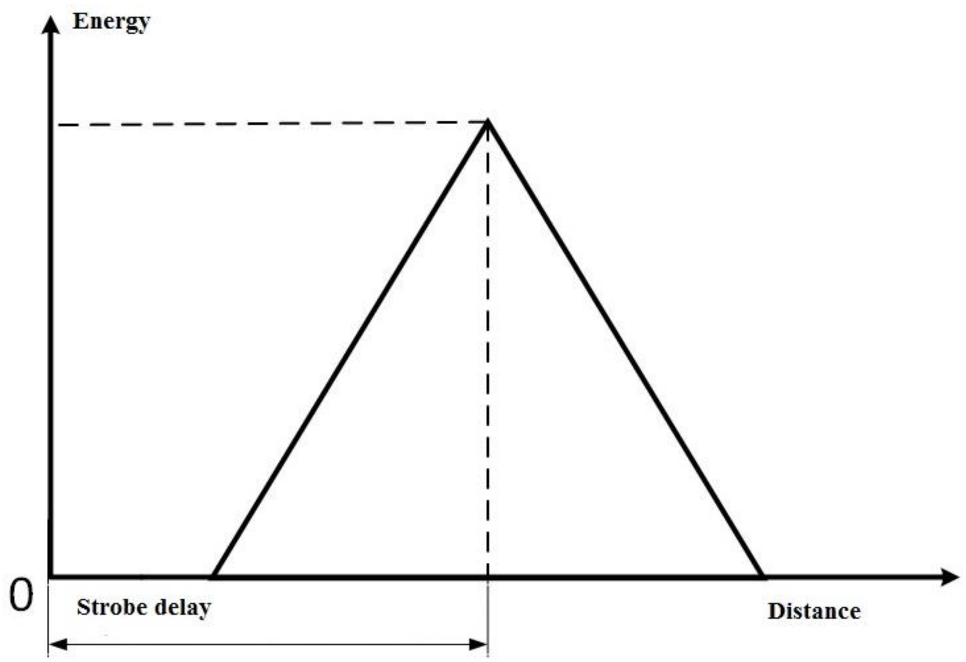

Fig. 1. Active vision area for rectangular illumination pulses and strobing at $\tau_L = \tau_g$, without taking into account reduction of light energy

Since the illumination radiation pulse reflected from the object, which is located at a distance corresponding to the strobing delay of the image intensifier tube, will be being received during the entire opening state of the image intensifier tube, with the duration pulses being equal, the centre of the active vision area will have the maximum energy in one point and will correspond to the strobing delay of the image intensifier tube [8].

The depth of the active vision area d_Z will depend upon the total duration of the illumination and strobing pulses of the image intensifier tube

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$$d_z = \frac{(\tau_L + \tau_g) \cdot c}{2}, \quad (1)$$

where τ_L – the illumination pulse duration,

τ_g – the strobing pulse duration of the image intensifier tube;

c – the speed of light.

In case the duration of the illumination pulse is less than that of the strobing pulse of the image intensifier tube, the active vision area will acquire the form of trapezoid. The maximum energy area will be somewhat extended, and the point, corresponding to the strobing delay of the image intensifier tube, will be located in the beginning of the maximum energy area (fig. 2) [9].

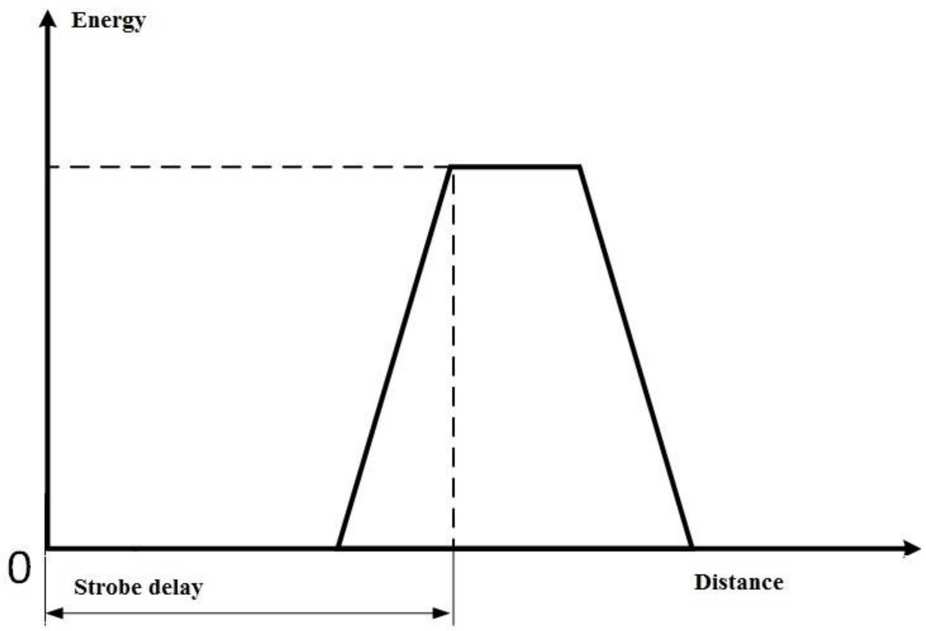

Fig. 2. Acitve vision area for rectangular pulses at $\tau_L < \tau_g$

The starting point of the active vision area d_{Zstart} at any duration relations depends upon the illumination pulse duration and is determined by the expression

$$d_{zstart} = \frac{(t_D - \tau_L) \cdot c}{2}, \quad (2)$$

where t_D – the strobing delay of the image intensifier tube;

τ_L – the illumination pulse duration;

c – the speed of light.

In the fig. 3, there are given expressions by means of which the major points of the active vision area, at $\tau_L < \tau_g$ for square waveforms, can be calculated.

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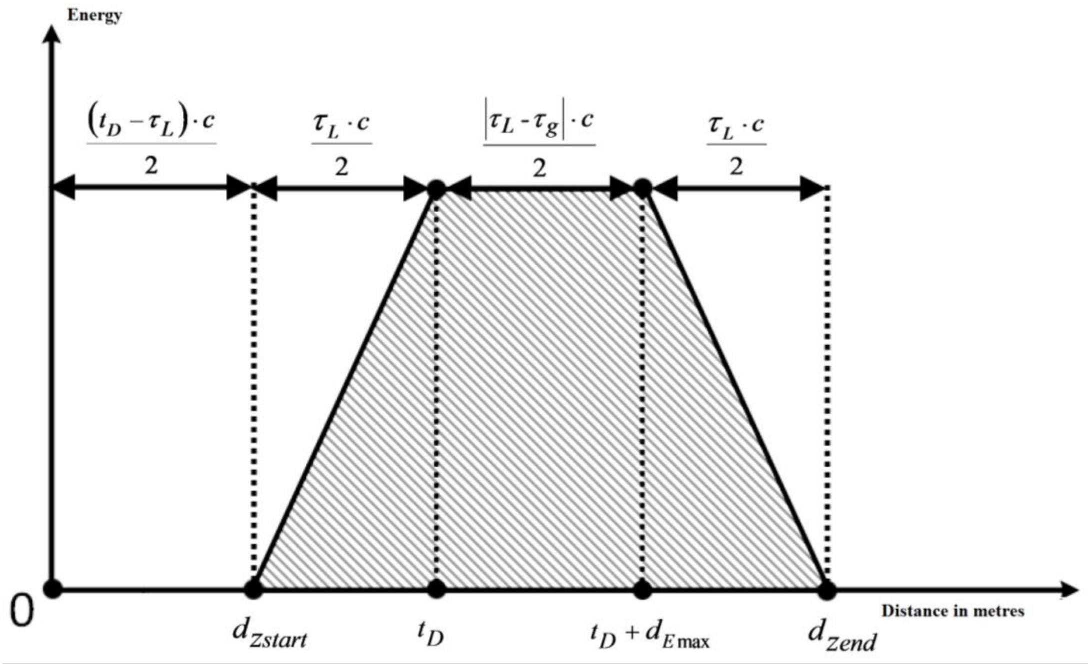

Fig. 3. Calculation of major points of the area for $\tau_L < \tau_g$

Practically, during the propagation in the atmosphere, the attenuation of the illumination is determined by two factors. One of them is reversely proportional to the square of the distance to the object, the other has a negative exponent. Therefore, the decrease of transparency of the atmosphere will be followed by the increasing distortion of the active vision area form [10].

Besides, rectangular short duration pulses with high amplitude are technically difficult to realise, therefore the calculation of the active vision area should be conducted taking into account the signal edges' duration, which will influence the form of the active vision area.

To calculate the form of the active vision area, taking into account the attenuation of light energy of the illumination proportionately to the square of the distance and attenuation in the hazy propagation atmosphere, the following expression is used

$$S_Z(L) = \frac{1}{L^2 \cdot \sigma^2(L)} \cdot \int_0^{\tau} S_g\left(t + \frac{2L}{10^{-9}c}\right) \cdot S_L(t)dt, \quad (3)$$

where τ – the integration time;

L – the distance;

$S_L(t)$ – the illumination signal;

$S_g(t)$ – strobing signal of the image intensifier tube;

$\sigma(L)$ – the coefficient of the optical quenching of the propagation atmosphere.

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In the fig. 4, there is a result of calculation of the active vision area for 15 metres (area 1) and 30 metres (area 2) at the same illumination pulse duration and strobing pulse duration of the image intensifier tube (60 ns), taking into account the illumination attenuation proportionately to the square of the distance and considering the optical quenching in the propagation atmosphere (light fog), which equals 20 dB/km.

Thus, it has been shown that at short observation distances, the active vision area is significantly distorted in the conditions of decreased transparency of propagation atmosphere. The area of the maximum energy of the active vision area is shifted from the centre of the area to its starting part, which leads to enhancement of the residual backscatter interference, light clutter from near objects, reduction of image contrast and tolerances in determination of the distance to the object under observation.

To minimise the consequences of the active vision area distortion, the duration of pulses of the illumination source should be reduced. The reduction of the duration of the pulses of the illumination source relative to the duration of strobing pulses of the image intensifier tube will result in the enhancement of steepness of the active vision area leading edge and the shift of the point, which corresponds to the strobing delay of the image intensifier tube, to the initial area of the active vision area.

The fig. 5 shows the result of calculation of the active vision areas for the distances of 15 metres (area 1) and 30 metres (area 2) in the parameters of the propagation atmosphere. The duration of the illumination pulse has been reduced twice, to 30 ns, the duration of the strobing pulse of the image intensifier tube has been increased to 90 ns.

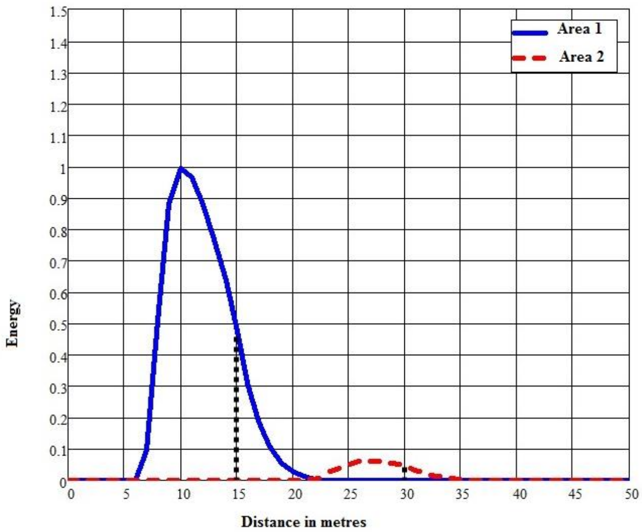

Fig. 4. The model of the active vision area for distances of 15 and 30 metres (the points mark the distance, which corresponds to the strobing delay of the image intensifier tube)

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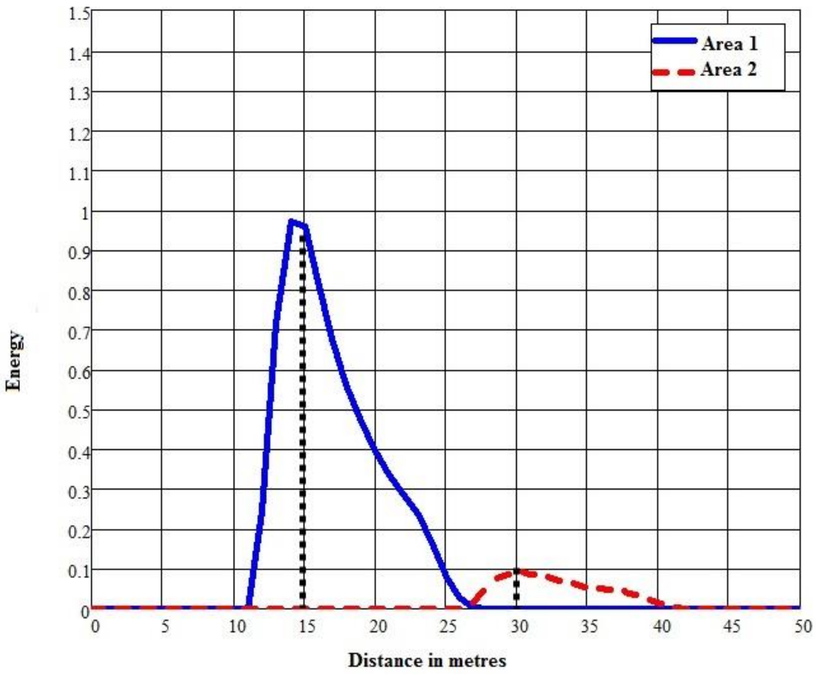

Fig. 5. The model of the active vision area (the distortions are compensated with the steepness of the leading edge of the active vision area)

Experimental research of the model of Active Pulse Television Measuring Systems (AP TMS)

To test the results of the modelling, a range of experiments under conditions of decreased transparency of the propagation atmosphere by means of AP TMS has been carried out. The system was developed by the authors of the article, at the Department of Television and Management, Tomsk State University of Control Systems and Radioelectronics (TUSUR).

The system comprises (fig. 6): the input objective, the image intensifier tube (IIT), which matches the objective, the image source (a monochrome CMOS 800 TVL) with increased sensitivity, the illuminator, the power source, the control blocks and computers with special software. The illuminator is the pulsed semiconductor laser which operates in the NIR.

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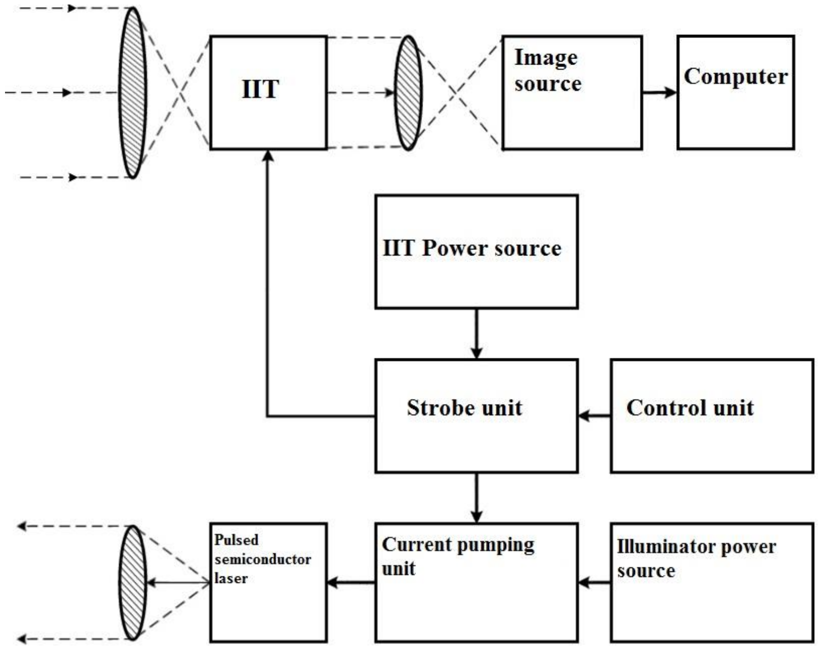

Fig. 6. Structural scheme of AP TMS

The appearance of the AP TMS model is seen in the fig. 7.
Technical characteristics of the AP TMS model:

- the system's range vision up to 200 metres;
- the system's vision angle 6–12 degrees;
- optical power of the illumination in the pulse 320 W;
- wave length of the illumination radiation 842 nanometres;
- pulse repetition frequency of the illumination 50–4950 hertz;
- duration of the illumination pulse 30–120 nanoseconds;
- duration of the IIT strobing pulses 30–120 nanoseconds;
- depth of the active vision area 9–36 metres.

Fig. 7. Appearance of the AP TMS model

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The experimental researches of the Active Pulse Television Measuring System have been carried out in the Big Aerosol Chamber (BAC) of V.E. Zuev Institute of Atmospheric Optics of Siberian Branch of the Russian Academy of Science.

The imitation of fog in the BAC was performed with the help of the fog generator which evaporated hydroglyceric mixture. Filling of the BAC with smoke was carried out by means of incineration of pine logs in a special furnace. As a rule, turbidity of the propagation atmosphere with fog or smoke kept till in the active uninterrupted mode of performance of the AP TMS (without strobing of the IIT, with active illumination), it was impossible to detect measuring test charts and objects of observation, located in the field of vision of the system. After that, the mixture of aerosols was evenly distributed in the entire BAC by ventilators during the course of 30 minutes.

In the fig. 8, 9 there are video frames of the AP TMS depending on the modes of performance and level of transparency of the propagation atmosphere.

During the experimental researches of the model of the AP TMS in the BAC, for testing the results of the simulation of the active vision area, the durations of illumination pulse and the IIT strobing pulse at constant delay of strobing were controlled.

The fig. 10 shows the frames of the AP TMS in the conditions of dense fog. The object of the observation was test chart (marked as a rectangular) placed at a distance of 21 metres (strobing delay of the IIT – 140 nanoseconds) with the strobing pulse delay of the IIT of 120 nanoseconds.

As it is seen from the fig. 10, the contrast of the image of the observed object, obtained at equal durations of the illumination and strobing pulses of the image intensifier tube, is significantly decreased due to impact of the backscatter interference, and the objects having the maximum brightness in the frame are located at a distance of 15 metres. On the contrary, the image of the observed object, obtained at a duration of the illumination pulse of 30 nanoseconds, has the maximum brightness in the frame and is distinctively more contrasting, which, on the whole, confirms the results of the simulation of the active vision area of the AP TMS.

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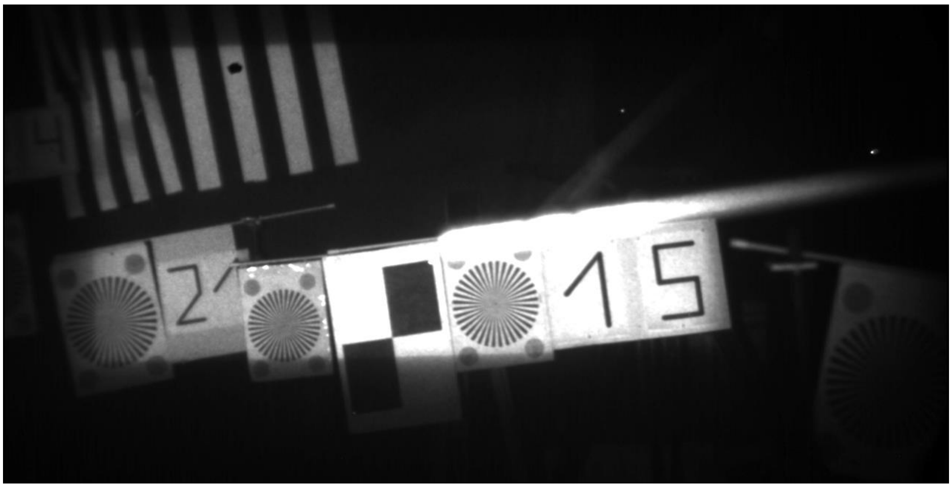
a



b

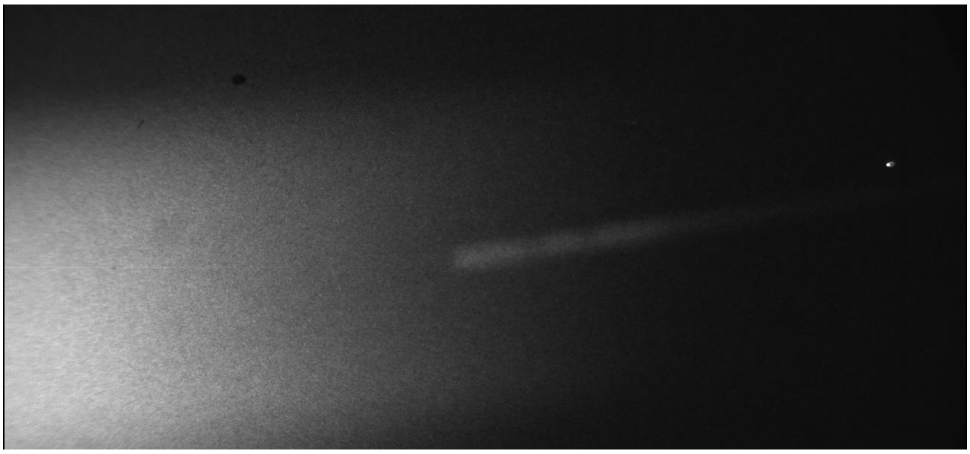


Fig. 8. Active uninterrupted mode of the AP TMS:
a) normal transparency of the propagation atmosphere; b) dense fog

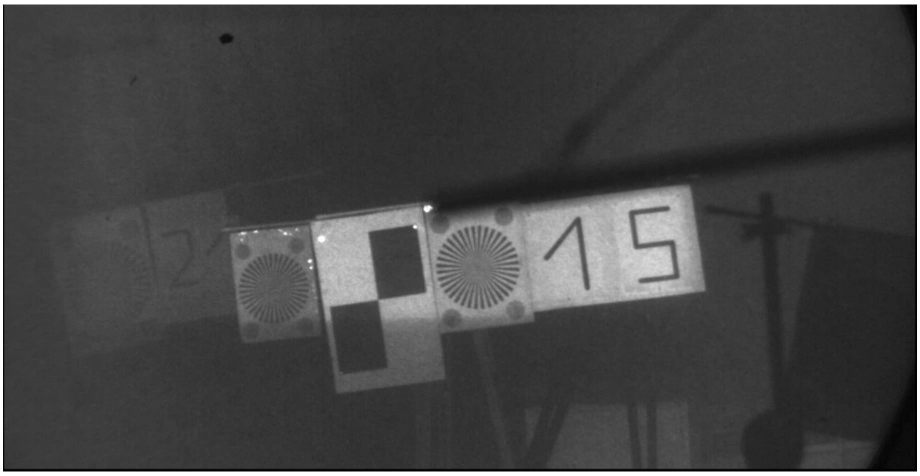


Fig. 9. Active pulse mode of the AP TMS, dense fog

a b

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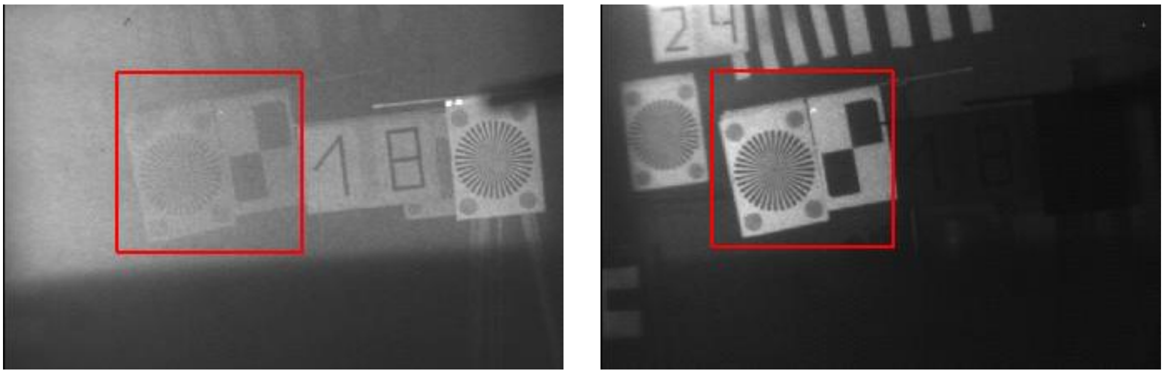

Fig. 10. The image of the object of observation:
a) duration of the illumination pulse – 120 nanoseconds,
b) duration of the illumination pulse – 30 nanoseconds

Shows the results of measuring the digital contrast of the object of observation depending upon duration of the illumination at constant duration of the strobing pulse of the IIT (120 nanoseconds) and strobing delay (140 nanoseconds). Duration of the illumination pulse is 120, level of contrast of the object observed is 97, 60 nanoseconds – 193, 30 nanoseconds – 230.

Conclusions

As a result of the researches, the models of the active vision areas were obtained, taking into account the attenuation of the optical radiation proportionately to the square of the distance and its quenching in the propagation atmosphere. It has been found out that if the durations of the illumination and strobing pulses of the image intensifier tube are equal, then in the conditions of low transparency of the propagation atmosphere, the form of the active vision area significantly distorts. The area of the maximum energy of the zone is shifted from the centre of the zone to its initial part, which leads to increase of the residual backscatter interference and, consequently, to decrease of the contrast of the image of the observed object. The decrease of the illumination pulse duration relatively to the duration of the strobing pulse of the IIT leads to increase of steepness of the leading edge of the active vision area and concentration of the maximum of energy in the point, corresponding to the temporary strobing delay of the IIT. High steepness of the leading edge of the active vision area enables efficient eliminating the backscatter interference, and the maximum energy in the point which corresponds to the temporary strobing delay of the IIT, increases accuracy of determination of the distance to the objects under observation. The results of simulation have been confirmed by experimental researches of the model of the AP TMS, which enables concluding that making efficient systems of navigation of transport modes in heavy weather conditions with the use of the AP TMS is feasible.

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SELECTION OF THE OIL TERMINAL TANK FARM SCHEME BY A SET OF CRITERIA

Aim: It is known that to simplify the process of transshipment of goods at the junction of different modes of transport, aimed at reducing the cost of transportation of liquid fuel, terminals are used, representing the capacity of different volumes (as cargo in this article means liquid fuel). The size of the designed terminal depends on many factors, but first of all on the mass of fuel to be stored due to inconsistency in the interaction of modes of transport with each other. In addition to this fundamental factor in the construction are considered and others, which in some cases may be important when choosing a terminal scheme. Such factors include, for example, construction costs, future maintenance costs, payback periods of the new terminal, etc.

Method: The development of the new terminal scheme is connected with the solution of a multicriteria problem with an objective choice of the best solution possible. This article shows such a solution using the developed algorithm [3].

Conclusion: When considering fuel transportation with the participation of terminals, the objective method makes it possible not only to determine the best ways of transportation, but also to find the best schemes of their tank farms.

Keywords: objective method, oil terminal, tank farm a variety of criteria, the technical scheme.

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ВЫБОР СХЕМЫ РЕЗЕРВУАРНОГО ПАРКА НЕФТЯНОГО ТЕРМИНАЛА ПО МНОЖЕСТВУ КРИТЕРИЕВ

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Для упрощения перевалки грузов при стыковке разных видов транспорта и для сокращения расходов при перевозке жидкого топлива используются терминалы, представляющие собой емкости разного объема (в качестве грузов в настоящей статье имеется в виду жидкое топливо). Объем проектируемого терминала зависит от многих факторов, в первую очередь – от массы топлива, которое нужно хранить при несогласованном взаимодействии видов транспорта. Также рассматриваются другие факторы, например, затраты на строительство и на будущее обслуживание, сроки окупаемости нового терминала и другие.

Цель: Разработать схему нового терминала для объективного выбора лучшего решения из возможных.

Выводы: При рассмотрении перевозок топлива с участием терминалов объективный метод позволяет не только определить лучшие пути транспортировки, но и найти лучшие схемы резервуарных парков.

Ключевые слова: объективный метод, нефтяной терминал, резервуарный парк, техническая схема.

Introduction

Almost in all branches of science and industry, there arises a necessity, after all conducted experiments, research and calculations, to compare several objects or technical suggestions, which are aimed at solving the same task, namely to finally choose one of them, which fully meets the given requirements (criteria). This scope of tasks also comprises the determination of the best scheme of the reservoir farm at the junction of the ground and water transport on the basis of comparison of different options, considering the given criteria. The essence of the suggested method to choose a promising option lies in the consideration of a number of criteria used for the process. The criteria used have different dimensions, so the choice of the best solution here is always associated with a certain processing (or reprocessing) of these criteria to bring them to a common "denominator", which is not an easy task. Practically, the right choice of the best solution even by three or four criteria makes a complicated task.

Considering the overall scientific and industrial interest towards the solution of the task of this kind, this paper shows the used method, which enables correct choosing the best solution from the criteria considered, including those which are contradictory.

Generally, the presented approach to the solution of this kind of tasks enables expanding the possibilities of the theory of the transportation management at the expense of increase of the quality of the transportation according to the criteria considered in each certain case. We will show the performance of the suggested approach when solving the certain task – the choice of the scheme of the terminal used for transshipment of the liquid fuel at the junction of the ground and water transport.

It needs pointing out that by this time, little attention has been given to the issue of the rational choice of the volume of the reservoir farm of the oil trans-

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shipment terminals. The establishment of the highly efficient and sustainable intermodal transportation system in the river and sea ports, as well as the rationalisation of the capacities of the existing oil terminals to ensure the interaction between the adjacent modes of transport, are described in the works [1–9]. However, the conclusions made in these works and the methods and approaches to the solution of the future tasks need to be improved,

When determining the rational volume of the reservoir farm of the oil terminals one uses the methods, which do not take into account the actual load of the reservoirs and the amount of the cargo transshipped. The determination of the rational capacity of the reservoir park without taking into account the interacting traffic flows and the productivity of transshipment, leads to the increase in idle time in ports and on railway tracks.

Problem statement

The choice of the scheme of the terminal is a task, the essence of which consists in the simultaneous assessment of a number of factors (criteria) and choice of their best final combination.

As for the main criteria, let us take the following ones:

K_{VT} – the volume of the terminal (m^3);

K_{CC} – the construction costs (thousand rubles);

K_{IT} – the installation time (days);

K_{FmC} – future maintenance costs (thousand rubles/year);

K_{RrC} – future reservoir repair costs (thousand rubles/year);

K_{El} – economic losses at the terminal’s downtime (thousand rubles/year);

K_R – risks associated with financial losses during the operation of the terminal (points).

In the task, there is hypothesis that the presence of a large amount of cargo at the terminal (at the set total volume) decreases the financial risks due to a lower possibility of the simultaneous failure of the most part of the terminal.

Solution of the task

The total volume of the terminal k_{VT}, when solving the task of the choice of its best scheme, should be set on the basis of the preliminary analysis and calculation of many factors, that ensure minimal financial losses of the participants of the transportation process, as it is them that are interested in a uninterrupted transportation of cargo (in this case – the liquid fuel). Thus, the choice of the scheme of the terminal at the set total volume is the important multicriteria task.

The construction costs of the terminal k_{CC} for each scheme are determined by the corresponding normative documents and are set in order to solve the task

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stated in the work. For each of the set options, the criteria k_{IT}, k_{FMC}, k_{RRC}, k_{EL}, k_R in this task are set and used during the solution as the initial conditions.

During choosing the best scheme of the terminal, below the four options are considered A_1, …, A_4 by the criteria given above. The options under consideration differ by the amount of reservoirs of the terminal at its constant total volume. At the same time, in the option A_1 one reservoir will be considered, with 2, 3, 4 reservoirs in A_2, A_3, A_4 respectively. Below, the values V of all the above-mentioned criteria for options A_1, …, A_4 are given, whereby it is not improbable that in practice, in a number of cases other or additional criteria can be considered, which can find a more substantial solution.

Thus, it is set that:

Option A1

V_{VT}^{A1} – 20 thousand m^3 (one reservoir);

V_{CC}^{A1} – 59 250 thousand rubles (here and below, the values of this criterion are indicated in accordance with the Table 1, whereby the columns of costs of construction and installation are put together; the same is for options A_2, A_3, A_4);

V_{IT}^{A1} – 105 days (table 1);

V_{FMC}^{A1} – 3150 thousand rubles/year;

V_{RRC}^{A1} – 2000 thousand rubles/year;

V_{EL}^{A1} – 12 000 thousand rubles/year;

V_{R}^{A1} – 0,6 (can be changed within 0÷1, whereby it is assumed that the more the level of risk is (that is, worse for the customer), the closer the figure is).

Option A2

V_{VT}^{A2} – 20 thousand m^3 (the total amount of two reservoirs, each of which is 10 thousand m^3);

V_{CC}^{A2} – 67 475.1 thousand rubles (table 1);

V_{IT}^{A2} – 176 days (table 1);

V_{FMC}^{A2} – 4400 thousand rubles/year;

V_{RRC}^{A2} – 2600 thousand rubles/year;

V_{EL}^{A2} – thousand rubles/year;

V_{R}^{A2} – 0,7.

Option A3

V_{VT}^{A3} – 20 thousand m^3 (the total amount of three reservoirs of 10, 5 and 5 thousand m^3);

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V_{CC}^{A3} – 67 639.21 thousand rubles (table 1);

V_{IT}^{A3} – 212 days (table 1);

V_{FMC}^{A3} – 5200 thousand rubles/year;

V_{RRC}^{A3} – 3000 thousand rubles/year;

V_{EL}^{A3} – 6000 thousand rubles/year;

V_{R}^{A3} – 0,8.

Table 1

Cost and time data

The volume of the reservoir, m^3	The cost of the structure, rubles	The cost of the installation, rubles	The time of the installation, days
100	806 000.00	550 560.00	12
200	1171 875,00	800 480,00	15
300	1500 000,00	1024 614,00	17
400	1687 500,00	1152 690,00	20
500	1640 000,00	1130 740,00	23
700	2250 000,00	1551 320,00	25
1000	2718 750,00	1848 750,00	26
2000	4680 000,00	2839 650,00	36
3000	7290 000,00	4649 280,00	51
5000	10 350 000,00	6600 829,00	62
10 000	20 955 000,00	12 782 550,00	88
20 000	37 500 000,00	21 750 000,00	105
30 000	45 000 000,00	26 100 000,00	125
50 000	75 000 000,00	42 000 000,00	160

Option A$_4$

V_{VT}^{A4} – 20 thousand m^3 (the total amount of four reservoirs of 5 thousand m^3 each);

V_{CC}^{A4} – 67 803,32 thousand rubles (table 1);

V_{IT}^{A4} – 248 days (table 1);

V_{FMC}^{A4} – 5800 thousand rubles/year;

V_{RRC}^{A4} – 3300 thousand rubles/year;

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V_{EL}^{A4} – 4000 thousand rubles/year;

V_{R}^{A4} – 0,9.

Solving the task in accordance with the algorithm [10], similar to the solutions of the tasks in [11, 12] by numerical values *V* of the criteria of the options A_1, …, A_4, let us construct the table 2. Due to the fact the value V_{VT} (the volume of the terminal) is constant for all the options (independent of the option of the scheme), it is omitted in the Table.

Table 2

The values *V* of the criteria for the options A_1, …, A_4.

The numerical numbers of the criteria	The options			
	A_1	A_2	A_3	A_4
V_{CC}	59 250 thousand rubles	67 475,1 thousand rubles	67 639,21 thousand rubles	67 803,32 thousand rubles
V_{IT}	105	176	212	248
V_{FMC}	3150 thousand rubles	4400 thousand rubles	5200 thousand rubles	5800 thousand rubles
V_{RRC}	2000 thousand rubles	2600 thousand rubles	3000 thousand rubles	3300 thousand rubles
V_{EL}	12 000 thousand rubles	8000 thousand rubles	6000 thousand rubles	4000 thousand rubles
V_R	0,6	0,7	0,8	0,9

Using the Table 2, let us construct the Table 3 of three places “*P*” (the values are in the square brackets) of the options considered (A_1, …, A_4) by each criterion and multiply these values by the corresponding “weight” ($0 \leq w \leq 1$) of the criterion (further below the “weight” will be given without inverted commas). It should be reminded that in accordance with [10], the more the weight (closer to 1) is, the more significant this criterion is, and, thus, the more refined the value of the place M ($P = M_{option}$) is, in relation to others by this criterion.

Let us assign the following values of the weight to the criteria:

$k_{CC} \rightarrow w = 1,0$; $k_{IT} \rightarrow w = 0,75$;
$k_{FMC} \rightarrow w = 0,90$; $k_{RRC} \rightarrow w = 0,70$;
$k_{EL} \rightarrow w = 0,70$; $k_R \rightarrow w = 0,65$.

Let us introduce the value of m on each of the options A_1, …, A_4, where m equals the sum of the values M on each of the options A_1, …, A_4 considered, into the table 3.

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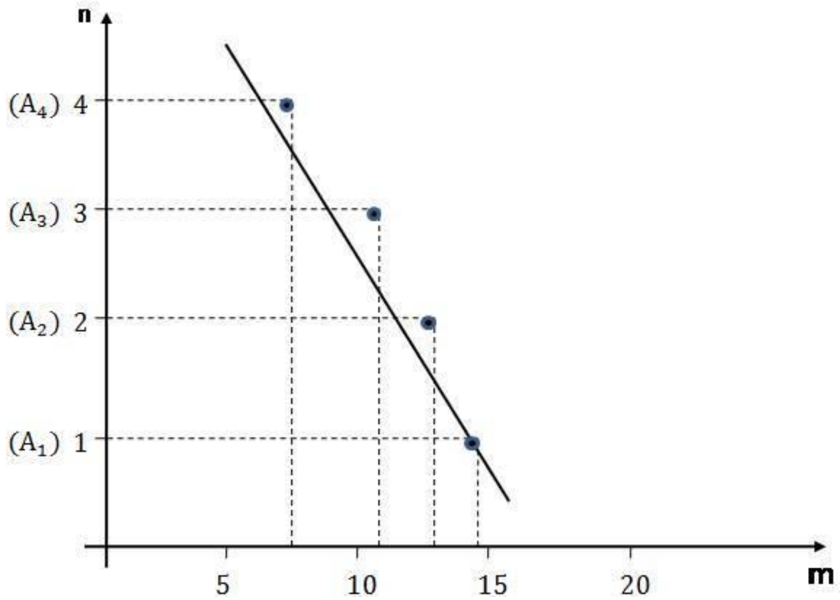
Table 3

The refined places $\mathcal{M}$ of the options in A_1, …, A_4 considering the weights *w* of the criteria

Пока-затель	The options			
	A_1	A_2	A_3	A_4
M_{CC}	[4] · 1 = 4	[3] · 1 = 3	[2] · 1 = 2	[1] · 1 = 1
M_{IT}	[4] · 0,75 = 3	[3] · 0,75 = 2,25	[2] · 0,75 = 1,5	[1] · 0,75 = 0,75
M_{FMC}	[4] · 0,9 = 3,6	[3] · 0,9 = 2,7	[2] · 0,9 = 1,8	[1] · 0,9 = 0,9
M_{RRC}	[4] · 0,7 = 2,8	[3] · 0,7 = 2,1	[2] · 0,7 = 1,4	[1] · 0,7 = 0,7
M_{EL}	[1] · 0,7 = 0,7	[2] · 0,7 = 1,4	[3] · 0,7 = 2,1	[4] · 0,7 = 2,8
M_R	[1] · 0,65 = 0,65	[2] · 0,65 = 1,3	[3] · 0,65 = 1,95	[4] · 0,65 = 2,6
m	14,75	12,75	10,75	8,75



The diagram of the values *m* and *n*

Using the results given in the table 3, let us construct the dependence m = *f*(n), where n = 1, …, 4 (the number of the reservoirs) – of the options A_1, …, A_4 respectively. The dependence is represented in the figure.

As it is seen from the given diagram, the distribution of m in relation to n represents a linear reverse relationship $m = m(n^{-1})$, which indicates that when choosing the options of volume schemes of the terminal reservoirs according to the criteria, using a single container is more preferable (the maximum value of m in the table and on the diagram), than several ones at a given total volume of containers.

The statement relates to those conditions (criteria) which were considered in this task. In other case (when considering other or additional criteria) the line-

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ar dependence (the equation of the straight line) can change, which may result in other relationship between *m* and *n*.

According to the result of the solved task, we can conclude that the method of the determination of the best solution out of the possible ones can change in practice in such tasks. The result of the solution is much dependent upon the initial parameters of the condition of the task, i.e. in our case upon the chosen criteria and their values and weights.

Summarising this chapter, we will use linear interpolation (the equation of a straight line through two points) for a spot check of one of the obtained values of $\mathcal{M}$ (the values are given in square brackets in table 3). Let us conduct checking by the criterion V_{IT} for the option A$_3$. Inserting the values V_{IT} and $\mathcal{M}_{IT}$ from the tabl. 2 and 3 into the mentioned equation: $V_k^{A3} = V_{IT}^{A3} = 212$, $V_{k1}^{A2} = V_{IT}^{A2} = 176$, $V_{k1}^{A1} = V_{IT}^{A2} = 248$, $\mathcal{M}_{k1}^{A2} = \mathcal{M}_{IT}^{A4} = 1$, $\mathcal{M}_{k1}^{A1} = = \mathcal{M}_{IT}^{A2} = 3$, We acquire (212–176) / (248–176) = ($\mathcal{M}_{k1}^{A3} - 1$) / (3–1), from where the unknown $\mathcal{M}_{IT}^{A3} = \mathcal{M}_{k1}^{A3} = 2$, which coincides with the value in the table 3.

Conclusion

The results of the researches in the sphere of multimodal transportation justified the further development of the theory of transportation in accordance with the tendencies of time, concentrating on reduction of losses and risks for the benefit of the customer.

In order to make a correct decision and evaluate the facility for transshipment of the liquid fuel, we considered the practical example of an objective choice of the best scheme of the reservoir farm.

To achieve the set purpose, in the suggested practical example the technical and economic parameters were used, which determined the reservoirs of the rational volume in order to minimise the current and the future costs at the set risks.

The suggested approach enables unifying the interests of the participants of the transportation market so that to minimise technical, financial and organisational losses.

According to the obtained final results, from the competing options the best one was chosen, judging by all criteria and considering their numerical values of importance. It should be noted, that the level of the objectivity of the solution increases at the expense of increase of the quality of the weights assigned to the criteria.

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REGULATION OF THE SUPPLY OF TRANSIT AND DECONSTRUCTION OF FREIGHT TRAINS TO THE TECHNICAL STATIONS

The article presents the results of the application analysis of the "Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks" dispatching technique.

Aim: To substantiate the effectiveness of the “Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks” dispatching technique.

Method: Simulation using the “Simulation of transport systems” (AvroraW) software package.

Results: The study revealed that the use of the "Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks" dispatching technique results in cutting idle time between operations, saving operating costs and in more uniform loading of station devices.

Conclusion: The results of the study will contribute to improving the efficiency of dispatching control of operational work.

Keywords: dispatching/supervisory control, efficiency, simulation modeling.

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РЕГУЛИРОВАНИЕ ПОДВОДА ТРАНЗИТНЫХ И РАЗБОРОЧНЫХ ГРУЗОВЫХ ПОЕЗДОВ К ТЕХНИЧЕСКИМ СТАНЦИЯМ

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Представлены результаты исследования применения диспетчерского приема «Регулирование (чередование) подвода транзитных и перерабатываемых поездов к станции с учетом положения в ее парках».

Цель: Обосновать эффективность реализации диспетчерского приема «Регулирование (чередование) подвода транзитных и перерабатываемых поездов к станции с учетом положения в ее парках».

Метод: Использовано имитационное моделирование с применением программного комплекса «Моделирование работы транспортных систем» (AvroraW).

Результаты: В ходе исследования установлено, что применение диспетчерского приема «Регулирование (чередование) подвода транзитных и перерабатываемых поездов к сортировочной станции с учетом положения в ее парках» ведет к снижению межоперационных простоев, экономии эксплуатационных расходов и более равномерной загрузке устройств станции.

Выводы: результаты исследования будут способствовать повышению эффективности диспетчерского регулирования эксплуатационной работы.

Ключевые слова: диспетчерское регулирование, эффективность, имитационное моделирование.

Introduction

During the last years increased train traffic bound to ports of the North-western Federal District resulted in major increase of railroad sections, train yards and port stations of Oktyabrskaya Railway (October Railway), which in its turn triggered delays in train traffic and increased cars downtime.

Multiple dispatcher techniques were developed over the years of existence of the railway transport dispatcher system [1].

Several methods and techniques targeted at train yards efficiency enhancement were used over the years of dispatching practice [2–4].

Special methods and complexes of analytic expression were developed as part of the study of workflow arrangement and information technologies at the St. Petersburg Moskovsky Marshalling Yard used in operational and economic feasibility calculations and in evaluation of multiple dispatching methods and techniques application efficiency.

This article presents the following technique: regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks.

Short profile of St. Petersburg Moskovsky Marshalling Yard

The St. Petersburg Moskovsky Marshalling Yard is a basic non-class railway marshalling yard of the St. Petersburg railway junction, and appears as a bidirectional station with in-line arrangement or receiving yards, gravity hump yard, sorting yard and departure yard in each classification system.

Classification systems are arranged parallel to each other, see fig. 1. The “Uneven” system works deals with car traffic arriving from train stations of the

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St. Petersburg railway junction, from Vyborg and Kouznechny stations and from Finland, Estonia, Lithuania, Latvia and Belarus. The "Even" system is used for car traffic coming from Mga (Sonkovo, Boudgoshsh, Kirishi, Volkhovstroy, Petrozavodsk, Babevo) and Moscow (Bologoe, Malaya Vishera, Tchudovo, Novgorod, Kolpino).

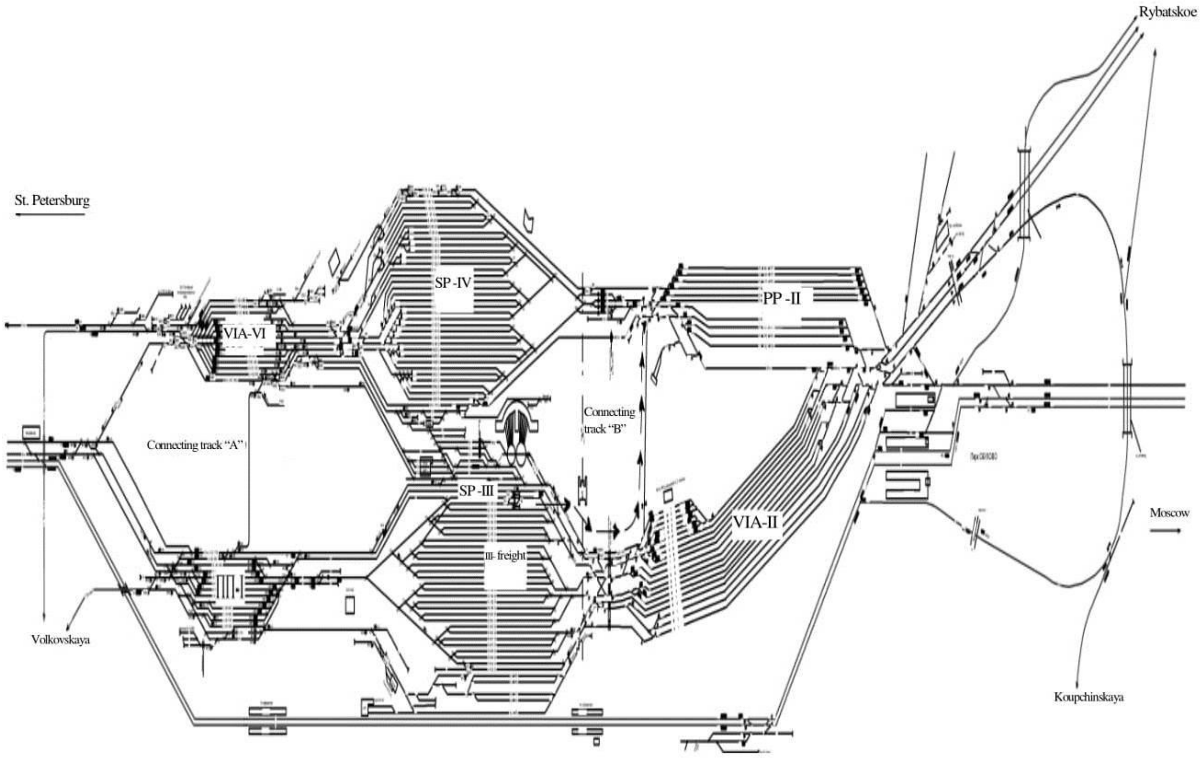

Fig. 1. St. Petersburg Moskovsky MarshallingYard

Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks

In order to arrange the station dispatcher shift paced operation in coordination with the Railroad Operational Control Center rational alteration approach of transit and remarshalling trains to the station shall be arranged in conformity with the marshalling devices and receiving and departure tracks rhythm of work. This results in enhancement of unhampered train admission at the station [5–7].

In order to arrange such efficient operation within the St. Petersburg Moskovsky Marshalling Yard, experiments were performed with the use of simulation modelling at different percentage ratios of transit and remarshalling trains arriving at the station during the design day.

To evaluate the efficiency of the train dispatching method the analysis was performed and informational implementation technologies were developed, as well as graphical characterization and algorithms were established in order to introduce this dispatching method in the simulation model.

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Simulation modelling was performed throughout the year (365 days) with plotting comparable diagrams of basic transport system elements involvement for each day with application of the dispatching technique under study and without application of this technique.

Schematically the “Regulation (alternate arrangement) of transit and re-marshalling trains approach to the station, with account for the situation in team tracks” technique is presented in fig. 2.

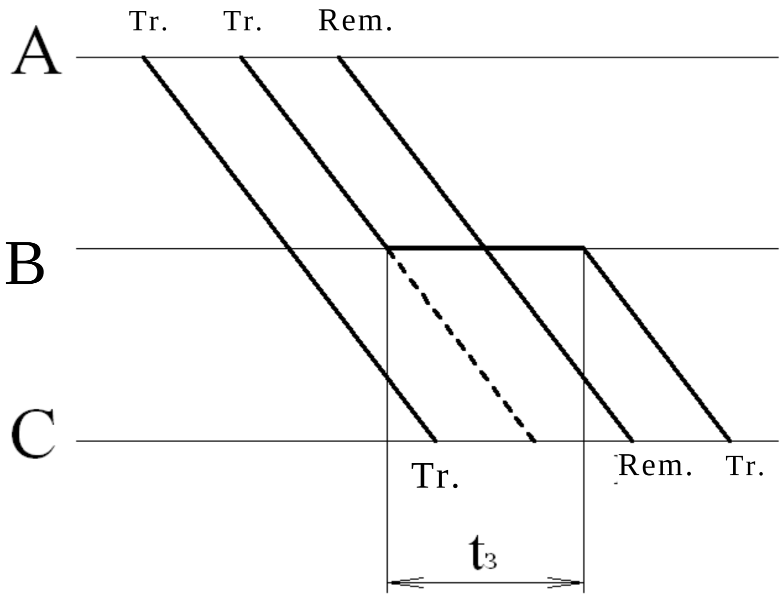

Fig. 2. Schematic presentation of the “Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks” technique

This fragment of the train schedule diagram shows two transit trains (Tr.) and one remarshalling train (Rem.) moving one after another from station A in the direction of marshalling station C with train-to-train interval (assumed equal to 10 minutes for calculation purposes). In order the trains reach station C on alternate basis, the second transit train shall be set for overtaking by the remarshalling train.

Irregularity of trains arrivals shall be accounted for in simulation modelling through the use of probability theory methods.

Formalized presentation of simulation model implementation for dispatching regulatory impact is shown in fig. 3.

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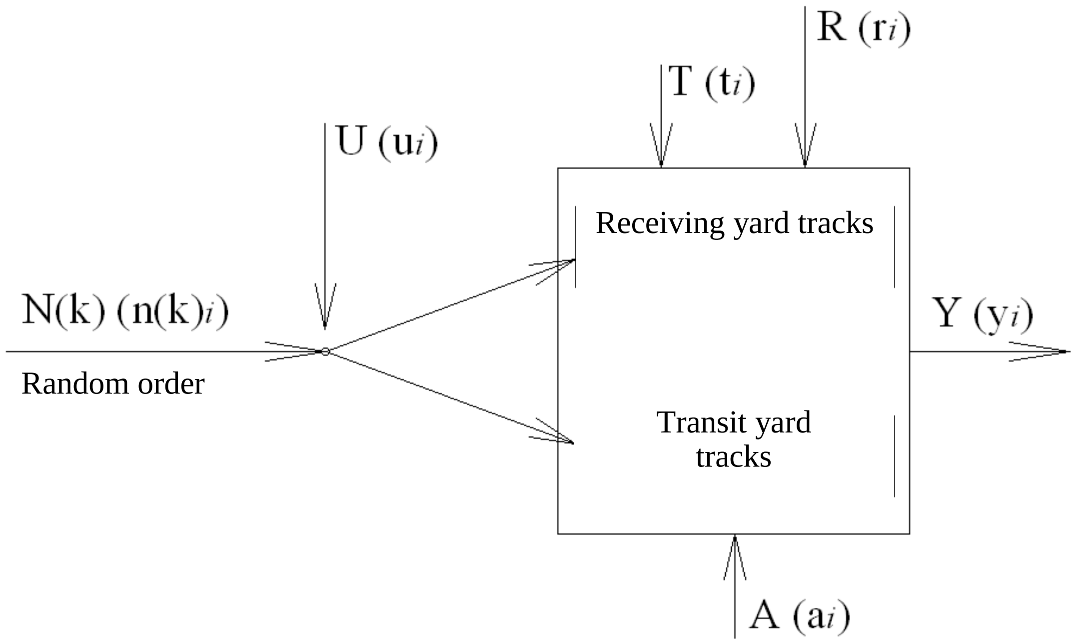

Fig. 3. Formalized presentation of implementation of the "Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks" dispatching technique within the simulation model framework

Fig. 3 shows all impacts and responses in vector form: $N(k)$ $(n(k)i)$ – incoming freight trains traffic flow, comprised of k categories (transit trains and remarshalling trains) and characterized by non-uniformity throughout the year, month, week and day; $T(ti)$ – duration of activities related to incoming trains traffic flow; $R(ri)$ – resources of the station; $Y(yi)$ – simulation model responses; $A(ai)$ – random component of the station operation process; $U(ui)$ –control impact.

Simulation modelling of processes implemented at the station makes possible to compare values of in-process downtimes for the following options: with and without application of the dispatching technique [8].

The fig. 4 shows the diagrams presenting the relationship between average in-process downtimes characteristic curves without application of the "Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks" technique and with application of this technique as function of remarshalling trains percentage.

In case the "Regulation (alternate arrangement) of transit and remarshalling trains approach to the train station, with account for the situation in team tracks" technique is not used, downtimes resulting from waiting for operations implementation shall be significantly higher than the ones in the case when such dispatching techniques are used.

Comparison of total downtimes caused by waiting for operations implementation showed that maximum effect due to application of the technique is reached when transit trains constitute 50 % of total trains traffic.

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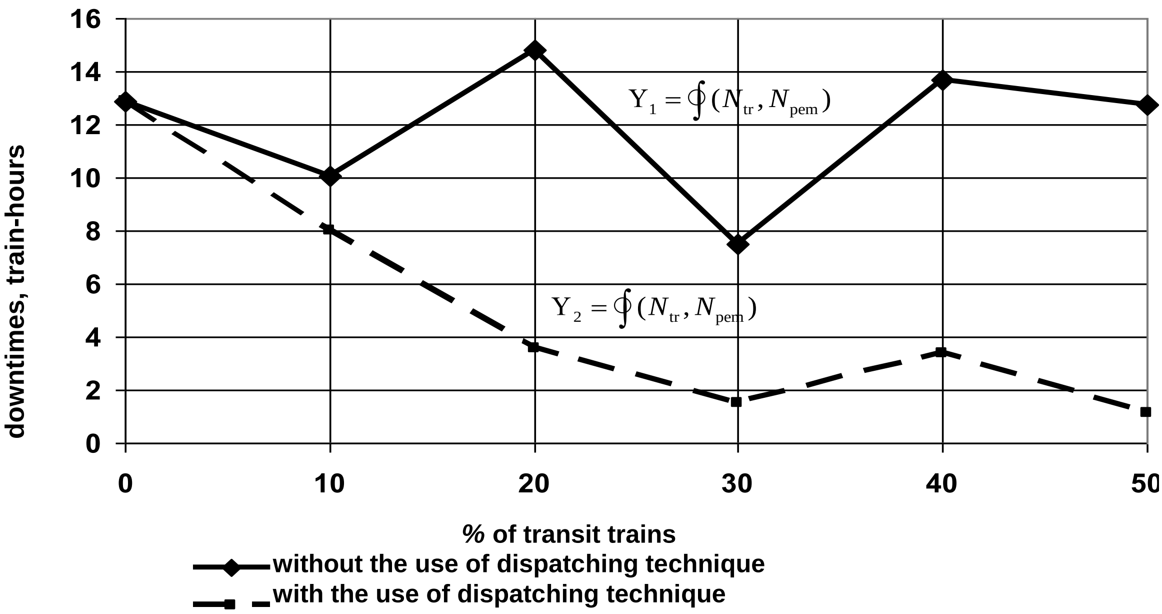

Fig. 4. Diagrams presenting relationship between average in-process downtimes and remarshalling trains percentage without application of the “Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks” technique and with application of this technique

The diagram shows that pronounced effect is observed when transit trains constitute 20 % of total trains traffic.

Model experiments were performed as part of the study and dispatching technique application efficiency was analyzed on the day-to-day basis throughout the year. Fig. 5 shows changes of total and average “waiting for service” delays during the first month without the ”Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks” technique and with application of this technique (transit trains constitute 50 % of total trains traffic).

Fig. 5. Diagrams of total and average “waiting for service” delays during the first month without application of the “Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks” technique and with application of this technique (transit trains constitute 50 % of total trains traffic)

Fig. 5 shows that in-process downtimes are subject to sizeable fluctuations during the month, while average delays caused by waiting for service with application of the dispatching technique (1,14 train-hours) are lower than average delays without application of this technique (12,76 train-hours).

Schedules of main transport system elements employment (standard day) without application of the “Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in

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team tracks" technique and with application of this technique are presented in fig. 6 respectively (50 % of transit trains).

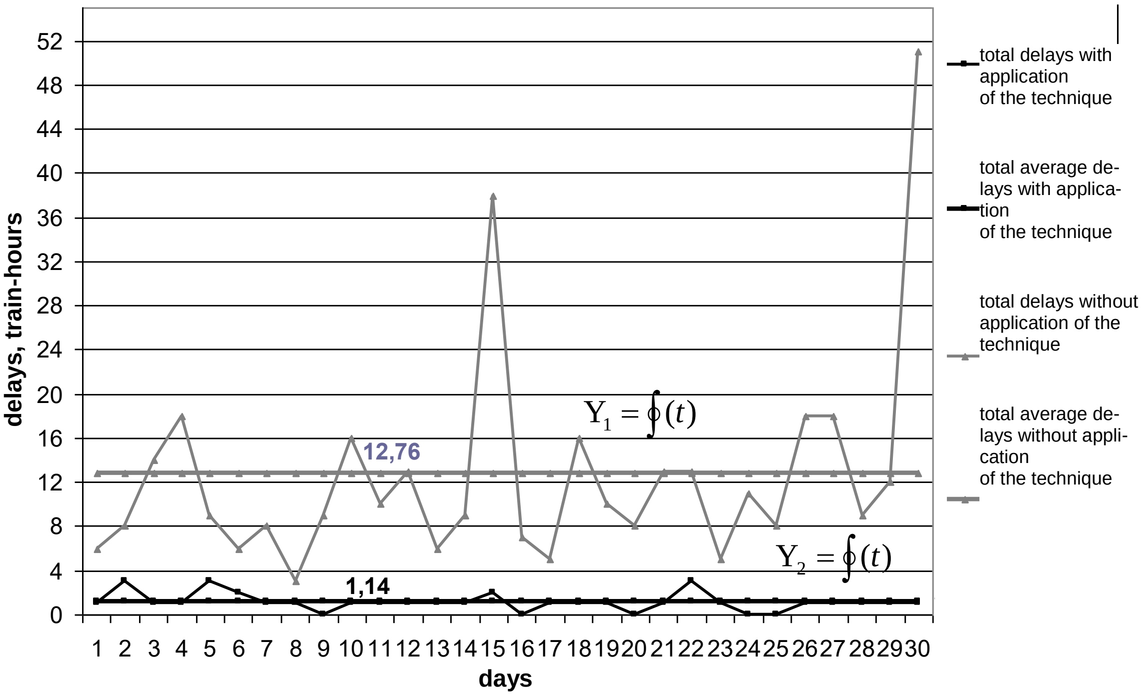

Fig. 5. Diagrams of total and average "waiting for service" delays during the first month without application of the "Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks" technique and with application of this technique (transit trains constitute 50 % of total trains traffic)

Calculations were performed aimed at evaluation cost savings based on application of this dispatching technique both for electric and diesel propulsion [9–11].

Results of operational cost savings calculations due to alternation of approach of freight trains in the ratio of 20% of transit trains and 80% of remarshalling trains can be presented by way of example.

RUR 14,7 th. per day with electric propulsion

RUR 13,5 th. per day with diesel propulsion

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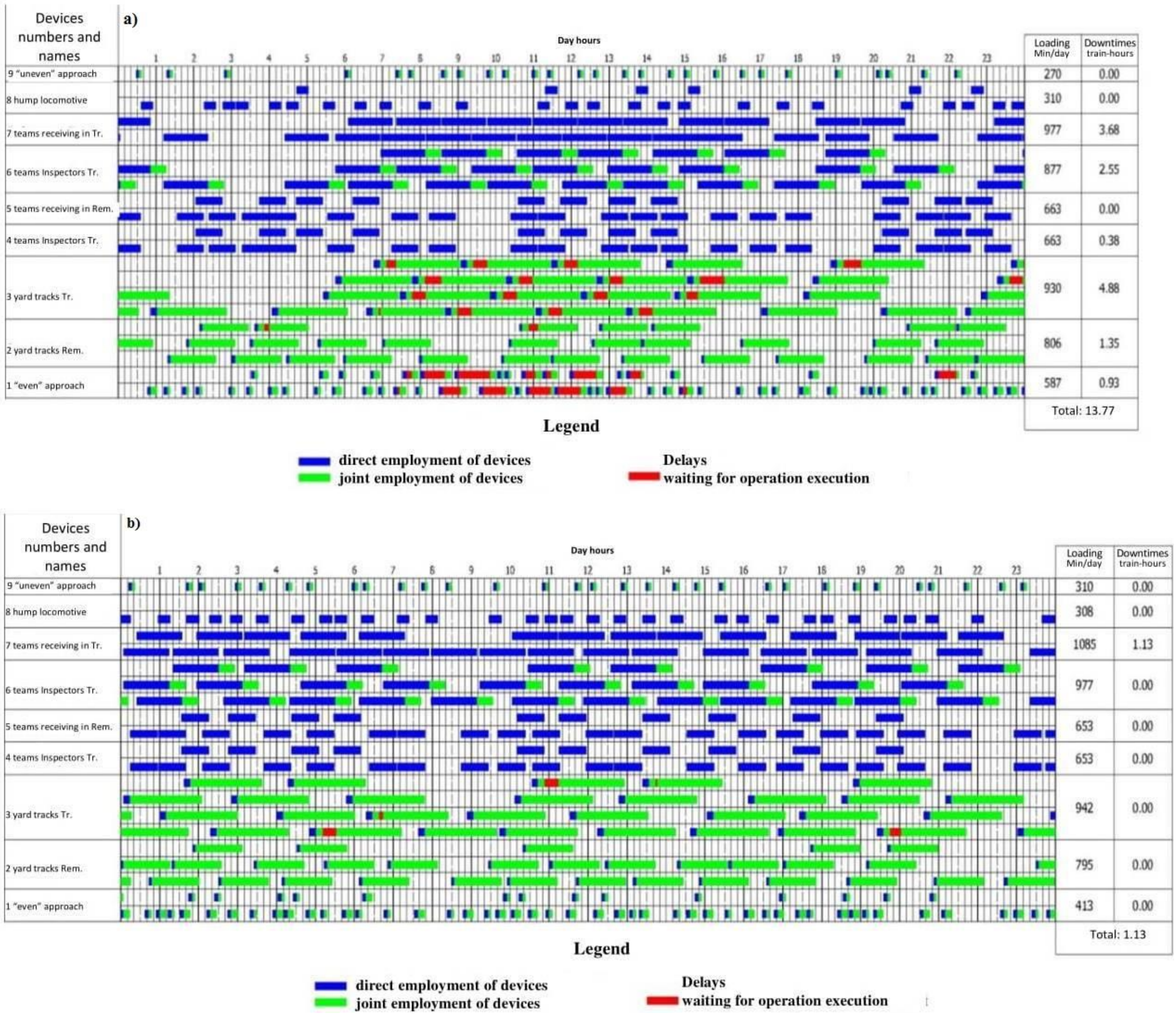

Fig. 6. Schedule of main transport system elements employment (standard day) without application of the "Regulation (alternate arrangement) of transit and remarshaling trains approach to the station, with account for the situation in team tracks" dispatching technique (a) and with application of the dispatching technique (b) (50 % of transit trains)

The study showed that application of the "Regulation (alternate arrangement) of transit and remarshalling trains approach to the station, with account for the situation in team tracks" dispatching technique results in cutting downtimes between operations, in saving operating costs and in more uniform loading of station devices.

Conclusion

Development of information technologies and implementation of state-of-the-art dispatching methods and techniques at freight stations, as well as algorithms of making economically viable operative decisions with respect to application of these techniques, promote trains operation according to set time schedules on railways of the country [12–14].

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USE OF EXPRESS CONTAINER TRAIN AS OPTIMIZATION METHOD OF RUBBER EXPORT CARRIAGE

Aim: The article is devoted to the issue of optimizing the export carriage of synthetic rubber produced in Russian, using the service of express container trains.

Methods: The analysis of volumes distribution of synthetic rubber production between the main Russian producers was made and an alternative option was proposed for the delivery of the products of the largest plant for the production of this raw material to foreign countries. To assess the economic efficiency of the carriage variant by express container trains, a comparison was made with the most commonly used method of rubber transportation by transport costs.

Results: Based on the results of the calculations, it was found that when transporting rubber in containers as part of express container trains, significant savings in transportation costs arise.

Practical significance of the work: The relevance of the proposed variant is due to the growth of cars production and the development of container transportations in the world. As a result, the transport component is reduced in the final cost of production, which allows suppliers to be more competitive in the market for the production of this raw material.

Keywords: express container train, synthetic rubber, carriage, container, cargo transshipment.

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ИСПОЛЬЗОВАНИЕ УСКОРЕННЫХ КОНТЕЙНЕРНЫХ ПОЕЗДОВ КАК СПОСОБ ОПТИМИЗАЦИИ ЭКСПОРТА КАУЧУКА

Цель: Описать оптимизацию экспортной поставки синтетического каучука, производимого в России, при помощи сервиса ускоренных контейнерных поездов.

Методы: Проанализировано распределение объемов производства синтетического каучука между основными российскими производителями, предложен альтернативный вариант поставки продукции крупнейшего завода по производству данного сырья в другие страны. Для оценки экономической эффективности сравниваются варианты перевозки в ускоренных контейнерных поездах с наиболее часто используемым способом транспортировки каучука на предмет транспортных издержек.

Результаты: Выявлено, что при перевозке каучука в контейнерах в составе ускоренных контейнерных поездов значительно экономятся денежные средства на транспортировку.

Практическая значимость работы: Благодаря росту производства автомобилей и развитию контейнерных перевозок в мире снижается транспортная составляющая в конечной стоимости продукции, что увеличивает конкурентоспособность поставщиков на рынке производства данного сырья.

Ключевые слова: ускоренный контейнерный поезд, синтетический каучук, транспортировка, контейнер, перетаривание груза.

Introduction

Globalisation, which began in the end of the previous century, is characterised by enhancement of competitiveness, increasing tempo of foreign investments, increase of volumes of intra-firm trade, establishment of transnational corporations in a number of branches, including the automobile industry [1].

The world has an increasing number of produced cars. In 2016, more than 94 million transport means were manufactured, which is 4 million more than in 2015 [2]. The increase of cars manufacture leads to increase of demand in rubber which

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is used for production of tires [3]. Far not all of the automobile concerns and spare parts works are located near rubber suppliers. Consequently, the demand arises to deliver these materials to manufacture sites by means of selecting the material transportation mean, which would be the most optimal for the producer.

Setting the task

Analysis of the world's rubber production volumes

In the production of tires, the natural and synthetic rubbers are used, the greatest part of which is located in Asia [4]. The second place is held by Europe, Middle East and Africa. The third place is held by the Americas (Tables 1 and 2) [5].

Table 1

World's volumes of natural rubber production

Region	Production volume in 2015, 10^6 kg	Production volume in 2016, 10^6 kg
Asia and Oceania	11 340	11 420
Europe, Middle East, Africa	597	645
The Americas	334	336
Total	12 231	12 401

Table 2

World's volumes of silicone rubber production

Region	Production volume in 2015, 10^6 kg	Production volume in 2016, 10^6 kg
Asia and Oceania	7508	7666
Europe, Middle East, Africa	3914	4130
The Americas	3085	3036
Total	14 507	14 831

The world's natural rubber production volume in 2016 made $12{,}4 \cdot 10^9$ kg, synthetic rubber production − $14{,}8 \cdot 10^9$ kg.

Russia with its 8,5 % ($1{,}3 \cdot 10^9$ kg per year) of the world's volume is a big manufacturer of synthetic rubber. The biggest national synthetic production enterprises are represented in the fig. 1 [6].

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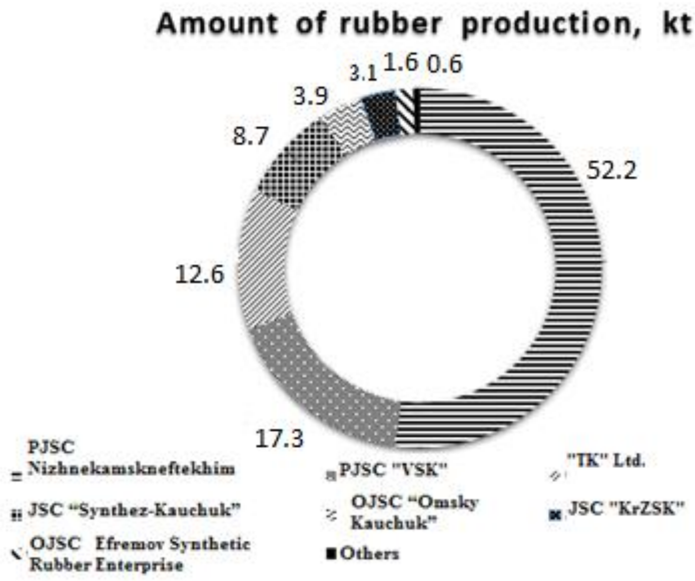

Fig. 1. Distribution of production of rubber in Russia in 2016

The biggest rubber producer in Russia is Public Joint Stock Company "Nizhnekamskneftekhim". The company is one of the top 10 synthetic producers in the world.

In 2016, more than 88 % of synthetic rubber selling operations of the company fell on international markets. 75 % of the volume was sold to big enterprises both in Russia and abroad.

The amount of export of the company for 2016 is distributed as follows (fig. 2) [7]:

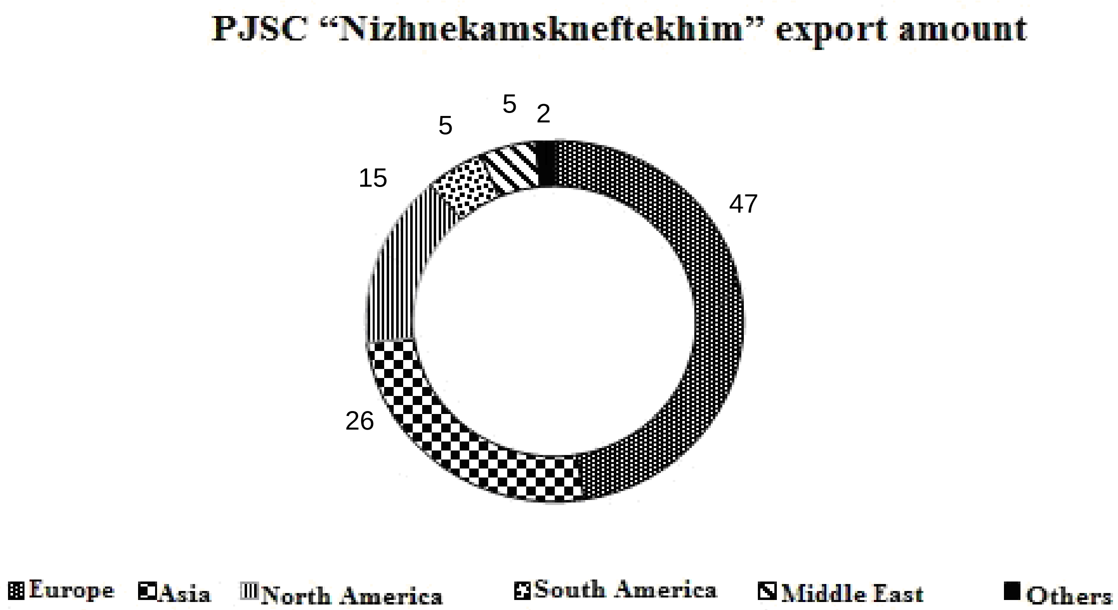

Fig. 2. Amount of Public Joint Stock Company "Nizhnekamskneftekhim" export, %

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It is seen from the diagram that the company exports the largest part of its product to Asia, Europe and North America. These regions are located at a great distance from producers. Moreover, export to some of the regions is possible only by sea.

Analysis of problems related to transportation of rubber as part of export

The city of Nizhnekamsk, where one of the leading rubber factories is located, is significantly remote from Russia's ports (fig. 3). For example, the distance to the port "Saint Petersburg" is approximately 2000 kilometres; to the Far East ports – 8000 kilometres. Another problem is large volumes of the production transported. Hence, the transportation of the production by car is irrelevant.

Fig. 3. Location of the rubber factory

With such long distances and large amounts of product transported, railway transportation is more profitable.

As a rule, rubber is transported in covered wagons. In case of the goods being transported to North America or Asia, there arises the necessity of transshipment leading to the goods being loaded from covered wagon to container for further seaborne transfer [8]. Since the amount of the goods transported is large, the procedure increases transport and time expenditures, which in its turn causes the delivery time to rise.

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When the goods are delivered to Europe, there is a possibility of ground transportation. Yet even in this case transshipment may not be avoided. This is related to different track gauge: 1520 mm in Russia and 1435 mm in Europe.

The problems arising during transportation of goods in covered wagons can be solved by virtue of organisation of transportation of goods in sea containers by railway. This will significantly decrease transport expenditures and delivery time, as there will be no demand in transshipment. This measure will help increase efficiency of such freight transportations [9]. To further reduce the delivery time and transport expenditures, this transportation may be arranged within express container train service.

The container train is a train which is made up from flatcars with containers thereon, running to the destination point without rearranging.

The advantages of express container trains are:

- possibility of transportation of large amounts of goods at one time. One express container train carries up to 150 TEU;
- decrease of delivery time. Absence of necessity of shunting works of containers at technical stations;
- fixed transit time during the journey;
- possibility of organisation of heavy containers delivery (loading to the carrying capacity of containers).

During transportation by express container trains there are two main drawbacks:

- dense arrival at the destination station. The difficulty of organisation of one-time export by car transport from the station.
- lack of empty containers in the regions of loading.

Options of solving the set tasks

Delivery of rubber to Europe, America and Asia is feasible on condition that the intermodal transportation is organised, which means application of several modes of transport.

Below the possible options of production delivery to a client's warehouse in terms of door-to-door shipping with the use of express container trains service is seen (Table 3).

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Table 3

Options of rubber transportation with the use of express container trains service

Route	Modes of transport in use	Tine of transportation by express container train, days	Technology of transportation
Export to Europe			
DOOR PJSC "Nizhnekamskneftekhim" ↓ Nizhnekamsk railway station (freight forwarder) ↓ Avtovo railway station (freight forwarder) ↓ the seaport "Saint Petersburg" ↓ a port of Europe ↓ DOOR a client's warehouse in Europe	Car Railway Sea	3	1. Empty container picking; 2. Delivering container for further loading to PJSC "Nizhnekamskneftekhim"; 3. Delivering the container with freight to Nizhnekamsk railway station; 4. Transportation by express container train by route Nizhnekamsk railway station − Avtovo railway station (freight forwarder); 5. Carrying the container to non-public railway of one of the seaport terminals with further stationing in the terminal; 6. Loading the container on a ship; 7. Seaborne transportation to a European port; 8. Stationing the container in the seaport terminal; 9. Loading the container on a car and carborne delivery to a client's warehouse
DOOR PJSC "Nizhnekamskneftekhim" ↓ Nizhnekamsk railway station (freight forwarder) ↓ Russia − Europe railway border station ↓ DOOR a client's warehouse in Europe	Car Railway	3 (to the border transit)	1. Empty container picking 2. Delivering container for further loading to PJSC "Nizhnekamskneftekhim"; 3. Delivering the container with freight to Nizhnekamsk railway station; 4. Transportation by express container train by route Nizhnekamsk railway station – border station; 5. Transloading to car transport and delivery to a client's warehouse, or loading the freight on standard-gauge railway, transportation to a European station and delivery to a client's warehouse

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Export to America			
DOOR PJSC "Nizhnekamskneftekhim" ↓ Nizhnekamsk railway station (freight forwarder) ↓ Vladivostok railway station (freight forwarder) / Cape Churkin station (freight forwarder) / Nakhodka – Vostochnaya station (freight forwarder) ↓ Commercial Port of Vladivostok Vladivostok Sea Fishing Port Vostochny Port ↓ DOOR a client's warehouse in America	Car Railway Sea	12	1. Empty container picking 2. Delivering container for further loading to PJSC "Nizhnekamskneftekhim" 3. Delivering the container with freight to Nizhnekamsk railway station 4. Transportation of container by express container train by route Nizhnekamsk railway station − Vladivostok railway station (freight forwarder) / Cape Churkin station (freight forwarder)/Nakhodka – Vostochnaya station (freight forwarder) 5. Carrying the container to non-public railway line of one of the terminals in the seaport and stationing in the terminal 6. Loading the container on a ship 7. Seaborne transportation to a port in America 8. Stationing the container in the seaport terminal 9. Loading the container on a car and delivery by car to client's warehouse
Export to Asia			
DOOR PJSC "Nizhnekamskneftekhim" ↓ Nizhnekamsk railway station (freight forwarder) ↓ Vladivostok railway station (freight forwarder) / Cape Churkin station (freight forwarder)/Nakhodka – Vostochnaya station (freight forwarder) ↓ Commercial Port of Vladivostok Vladivostok Sea Fishing Port Vostochny Port ↓	Car Railway Sea	12	1. Empty container picking; 2. Delivering container for further loading to PJSC "Nizhnekamskneftekhim"; 3. Delivering the container with freight to Nizhnekamsk railway station; 4. Transportation of container by express container train by route Nizhnekamsk railway station − Vladivostok railway station (freight forwarder) / Cape Churkin station (freight forwarder) / Nakhodka – Vostochnaya station (freight forwarder); 5. Carrying the container to non-public railway line of one of the terminals in the seaport and stationing in the terminal; 6. Loading the container on a ship; 7. Seaborne transportation to a

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DOOR a client's warehouse in Asia			port in America; 8. Stationing the container in the seaport terminal; 9. Loading the container on a car and delivery by car to client's warehouse
DOOR PJSC "Nizhnekamskneftekhim" ↓ Nizhnekamsk railway station (freight forwarder) ↓ Russia-China border station ↓ railway stations near China's ports ↓ China's ports ↓ Asia's ports ↓ DOOR a client's warehouse in Asia	Car Railway Sea	16–22	1. Empty container picking; 2. Delivering container for further loading to PJSC "Nizhnekamskneftekhim"; 3. Delivering the container with freight to Nizhnekamsk railway station; 4. Transportation of container by express container train by route Nizhnekamsk railway station – Russia – China border station; 5. Loading the containers on standard-gauge railway; 6. Transportation of containers by express container train from Russia – China border station to stations near ports in China; 7. Delivery of the container to a seaport terminal; 8. Loading the container on a ship; 9. Seaborne transportation to an Asia's port; 10. Stationing the container in the seaport terminal 11. Loading the container on a car and carborne delivery to a client's warehouse

Results of the studies

One of the factors of increase of freight transportation efficiency is tariff setting which is based on the prime cost of transportation [10, 11]. To compare options of transportation of rubber in covered wagons and in express container trains, the transport expenditures were calculated for one tonne of freight [12].

For calculations the today's most widespread transport pack for carrying rubber has been chosen, i.e. corrugated box placed on a pallet. During transportation in covered wagons, the wagon type 11-280 with the volume 138 cubic metres was used, by express container train – 40DC sea container [13].

All data concerning the freight, wagon and container necessary for calculations are given in the Tables 4 and 5.

According to the results of the calculations of the amount of freight in the wagon and in container, the optimal number of pallets in the transport mode was chosen, using the scheme of arrangement and carrying capacity [14].

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The authors have calculated the costs of transportation by the route DOOR PJSC "Nizhnekamskneftekhim" – Avtovo railway station (freight forwarder) with delivery by covered wagons and in containers on express container train for further forwarding to Europe (Tables 6 and 7). Since the cost of transportation by sea and, consequently, further transportation by car or in containers by railway through Europe will be the same, the comparison of carborne transportation cost [15] from PJSC "Nizhnekamskneftekhim" to the departure station (Nizhnekamsk station) and of railway transportation by the route Nizhnekamsk station – Avtovo station (freight forwarder) is made.

Table 4

Determination of the amount of freight in covered wagon

138 cubic metres covered wagon		
Parameter	Unit of measurement	Value
Size of the box	mm	1200 × 800 × 1200
Size of the pallet	mm	1200 × 800 × 145
Freight density	kg/m^3	950 000
Freight weight	kg	1095
Freight weight including the pallet	kg	1107
Inside dimensions of the wagon body	mm	15 724 × 2764 × 2800
Wagon doors dimensions	mm	3802 × 2334
Carrying capacity of the wagon	kg	68
Number of pallets according to carrying capacity of the wagon	pieces	61
Number of pallets according to arrangement of freight inside the wagon	pieces	66
Net weight of the freight without pack in one wagon	kg	66 795
Gross weight of the freight without pack in one wagon	kg	67 527

Table 5

Determination of the amount of freight in container and on a wagon

40DC container on a 25 metres long platform		
Parameter	Unit of measurement	Value
Size of the box	mm	1200 × 800 × 1200
Size of the pallet	mm	1200 × 800 × 145
Freight density	kg/m^3	950 000
Freight weight	kg	1095
Freight weight including the pallet	kg	1,107
Inside dimensions of the container	mm	12 022 × 2352 × 2395
Carrying capacity of the container	kg	26 580
Number of pallets according to carrying capacity of the container	pieces	24

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40DC container on a 25 metres long platform		
Parameter	Unit of measurement	Value
Number of pallets according to arrangement of freight inside the container	pieces	25
Net weight of the freight without pack in one container	kg	26 280
Gross weight of the freight without pack in one container	kg	26 568
Net weight of the freight without pack on one wagon	kg	52 560
Gross weight of the freight without pack on one wagon	kg	53 136

Table 6

Calculation of transport expenditures per one tonne of freight transported in covered wagons, rur

Parameter	Value
Supply of car to PJSC "Nizhnekamskneftekhim" and transportation by car from the factory to Nizhnekamsk station (three runs)	20 000
Loading and unloading of the freight from the car to the covered wagon	26 000
Fastening materials	6000
Lock and seal devices, 2 pieces	600
Additional expenditures (Loading scheme, weighing, document procedures)	1300
Supply of the covered wagon to the route	40 000
Railway tariff of the route Nizhnekamsk station−Avtovo station (freight forwarder)	94 932
Loading of the freight from the covered wagon to sea company owned container	26 000
Total cost of the freight transportation in covered wagon	**214 832**
Total cost of transportation of 1000 kg of the freight	**3181,42**

Table 7

Calculation of transport expenditures per 1000 kg of the freight transported by express container train

Parameter	Value
Supply of two sea company owned 40DC containers	12 000
Picking of the two empty containers from the line, supply of the containers for loading to PJSC "Nizhnekamskneftekhim", delivery by car from the factory to Nizhnekamsk station	22 000
Lock and seal devices for two containers	600
Additional expenditures (Loading scheme, weighing, document procedures)	1300
Supply of the 80 feet platform for the route	20 000
Railway tariff of the route Nizhnekamsk station−Avtovo station	48 014

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Parameter	Value
(freight forwarder)	
Total cost of transportation in two 40DC containers with a 25 metres long platform	**103 914**
Total cost of transportation of 1000 kg of the freight	**1977,05**

Discussion of the results

The results of the studies have shown that with transportation of rubber from Nizhnekamsk to Europe by express container train service, transport expenditures per 1000 kg of the freight decrease by more than 1200 rubles.

Provided that one container train can carry up to 74 40DC containers, the savings will make more than 2,3 million rubles as compared to transportation of rubber in covered wagons.

Conclusion

To conclude, it needs to pointed out that the development of express container trains allows significant reduction of transport expenditures in the final cost of the product, increase of safety of the transported freight and, consequently, enhancement of competitiveness of railway transport.

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EFFICIENCY OF INTRODUCTION OF THE ENERGY MANAGEMENT SYSTEM IN RUSSIAN INDUSTRIAL COMPANIES

Aim: The purpose of the study is to present an overview of national and international energy management systems and suggest activities to enhance the quality of the realisation of the energy management systems in Russian industrial companies.

Methods: The authors have used the description of the energy saving and energy management systems directions under research, the analysis of the qualitative properties of the energy management systems in use, structural and functional method for the development of the general structure and stages of functioning of the energy management systems.

Results: During the research, the authors have revealed the necessity to unify separate directions of the energy saving policies of Russia's industrial companies into the energy management system that is a subsystem of the overall enterprise management, combining the company's strategic goals, energy auditing, training personnel in energy saving and energy efficiency enhancement, energy resources recording system, the formation, realisation and monitoring of the energy saving programme, and automation of the energy saving and energy efficiency enhancement activities.

Conclusion: The realisation of the suggested measures will enable forming the conditions for the transition to a large-scale implementation of the energy management system, that fosters the realisation of the state policy in energy saving and energy efficiency enhancement.

Keywords: energy management system, increasing energy efficiency, development of the energy policy.

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ЭФФЕКТИВНОСТЬ ВНЕДРЕНИЯ СИСТЕМЫ ЭНЕРГЕТИЧЕСКОГО МЕНЕДЖМЕНТА В ПРОМЫШЛЕННЫХ КОМПАНИЯХ РОССИИ

Цель: Представить обзор зарубежных и российских систем энергетического менеджмента и предложить мероприятия, направленные на повышение качества реализации систем энергетического менеджмента в российских промышленных компаниях.

Методы: Использовались описание исследуемых направлений энергосбережения и систем энергетического менеджмента, анализ качественных характеристик применяемых систем энергетического менеджмента, структурно-функциональный метод для разработки общей структуры и этапов функционирования систем энергетического менеджмента.

Результаты: В ходе исследования выявлена необходимость объединить частные направления энергосбережения российских промышленных компаний в систему энергетического менеджмента, которая является одной из подсистем общей системы управления предприятием, соединяющей стратегические цели компании, энергетический аудит, подготовку персонала по вопросам энергосбережения и повышения энергетической эффективности, систему учета энергоресурсов, формирование, реализацию и мониторинг программы энергосбережения, а также автоматизацию деятельности по энергосбережению и повышению энергетической эффективности.

Выводы: Реализация предложенных мер позволит сформировать условия для перехода к широкому внедрению системы энергетического менеджмента, способствующего реализации государственной политики в сфере энергосбережения и повышения энергетической эффективности.

Ключевые слова: система энергетического менеджмента, повышение энергоэффективности, разработка энергетической политики.

Introduction

Currently, in today’s enterprise management practices, the problem of increasing energy efficiency is becoming more acute. In other countries, there are active actions being taken to develop and realise projects of energy efficiency bolstering [1]. Embedding these projects is also one of the directions of Russia’s industrial enterprises’ development.

The increase of relevance of energy saving caused by the world’s global and regional economic downturns, led to necessity of improving the international standardisation system of energy management, the basic objectives of which are regulation and disclosure of principles of development of energy efficient

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processes of industrial enterprises' operation, and elaboration of rational energy management policies of enterprises.

The energy management in enterprises comprises a range of functions, the fulfillment of which gives a detailed information on major fuel and power consumers, main industrial processes' efficiency, reduction of power consumption. All this actually makes up the energy management system (EMS).

The active pace of development of the energy management technologies is frequently connected with the emergence of economic crises, during which the issues of production competitiveness, distribution or consumption of fuel and power resources (FPR) become particularly acute [2]. One of the most significant stages to determine transition to today's stage of development of systemised approaches to energy conservation, was the 1970s energy crisis, that triggered elevation of oil prices and, naturally, inflation rates [3]. One of the crucial consequences of the crisis was a widespread dissemination of energy saving technologies, which are one of the main instruments of enhancement of competitiveness of industrial enterprises' products.

In this respect, by the end of 1970s, the governments of several states (Germany, the USA, Japan) began implementing legal mechanisms to incentivise energy conservation on a national scale. This led to the emergence of separate directions in the sphere of FPR consumption. In the same period, the first concepts of energy efficiency management in connection to ecological problems of the regions with industries were formulated [4].

Thus, the big industrial enterprises' coming to the idea of the energy management was connected with the acute need in saving resources, cutting down indirect expenditures on production, and reducing environmental pollution.

Gradually, the realisation of separate directions in the sphere of energy conservation was becoming more systemised in the majority of industrial states, which lead to development of the International Energy Management Standard [5]. The systemised idea of energy management sees a close interrelation with other types of management: operation of production processes, production logistics, ecology management and HR management [6]. Thus, the today's energy management is a continuation of an early energy saving concept.

The problems of the implementation of EMS in Russia's industrial enterprises are connected with the peculiarities of the modern stage of social and economic development, which is characterised by development of private ownership in the industrial sector and transition to decentralised planning. Some authors maintain that the energy crisis negatively influenced the processes of formation of internal approaches to energy saving, opening export channels for local energy resources [3]. A number of researchers point out that a growing importance of energy saving in Russia relates to transition to market economy in the early 1990s: the energy resources' prices in the decentralised system of industrial production naturally grew by 15–20 % on average, with the general level of energy intensity of the industrial products saved [3].

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The peculiarities of development of the Russian energy infrastructure also determined the investment policy. Thus, in 1990s the volume of financing of the energy sphere dropped substantially, despite significant moral and physical obsolescence of equipment in the enterprises of this branch. This also had a bearing on informational and technical, and monitoring facilities, which provide analysis of the current and future state of the energy infrastructure elements. Because of this, some producers perform with low efficiency, and their prices and tariffs on an international scale are not competitive.

One of the most significant factors to encourage development and implementation of EMS in today's Russia was its joining the World Trade Organisation. Joining WTO, again, emphasised low competitiveness of national products in the international markets due to low energy efficiency of industries. Russia's joining WTO was preceded by a number of federal legislative acts, which reflected the state position on improvement of energy and ecology related aspects of Russia's economy [7]. At present, the Federal Energy Saving Programme up to 2020 is in action. It is aimed at decreasing the energy intensity of GDP of Russia by 13,5 %.

Generally, implementing EMS realises the systemised approach to management of FPR. However, for the majority of Russia's industrial companies the implementation of EMS is more driven by the legislation of the Russian Federation, and to a lesser extent by the actual intention to increase energy efficiency at the expense of such implementation. This can be explained not only by a low experience in realisation of this system, but also by lack of methods of assessment of the results of EMS implementation efficiency.

Setting the Task

Among the most serious problems of realisation of the energy management systems in Russia there are industrial companies' administrations' lack of understanding of the relevance of the energy policy, the boundaries of responsibility in its realisation and unclear documentation support connected with the realisation and implementation. These contradictions result in low efficiency of organisation of EMS in industrial enterprises.

Thus, during application of EMS in Russian enterprises, there will be a topical task to solve – the development of an efficient energy policy.

Now, a number of big Russian companies are realising projects of implementation of EMS on the basis of ISO 50001:2011 requirements (Russian National Standard (GOST) R ISO 50001-2012). Among these companies there are Rosneft, Transneft, Sibur Holding, Surgutneftegas, Lukoil, Rossiiskiye Seti (Rosseti), INTER RAO, Rosatom, RZhD, Gazpromneft, etc.

The Standard [8] sets requirements for EMS on development and realisation of the energy policy, tasks, objectives and plans, in which legal requirements and information concerning utilisation of energy are considered.

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The purpose of the developed ISO 50001 consists in an enterprise's providing a well-structured and all-encompassing guideline on optimisation of energy resources consumption and systematic management of this process, to ensure continual improvement of energy efficiency.

The fig. 1 shows a model of EMS in accordance with ISO 50001, which is based upon the cycle: plan (planning) – do (implementation and operation) – check (checking) – act (internal audit, management review, continual improvement). As it can be seen from the fig. 1, the energy policy is a starting point and consequently the basis of any EMS. The ISO 50001 defines the energy policy as "the overall intentions and direction of an organisation related to its energy performance, as formally expressed by top management. The energy policy provides a framework for action and for the setting of energy objectives and energy targets" [9].

The implementation of EMS is aimed at following:

- energy provision;
- measuring, providing documents and reports on energy utilisation;
- procurement;
- developing methods of assessment of efficient utilisation of energy by equipment, systems and processes.

In order to survey best practices and efficiency of implementation of EMS in accordance with ISO 50001 provisions, in 2015, the Ministry of Energy of the Russian Federation with the participation of Russian Energy Agency of the Ministry of Energy, conducted monitoring of management of energy efficiency and implementation of EMS in Russian companies [10].

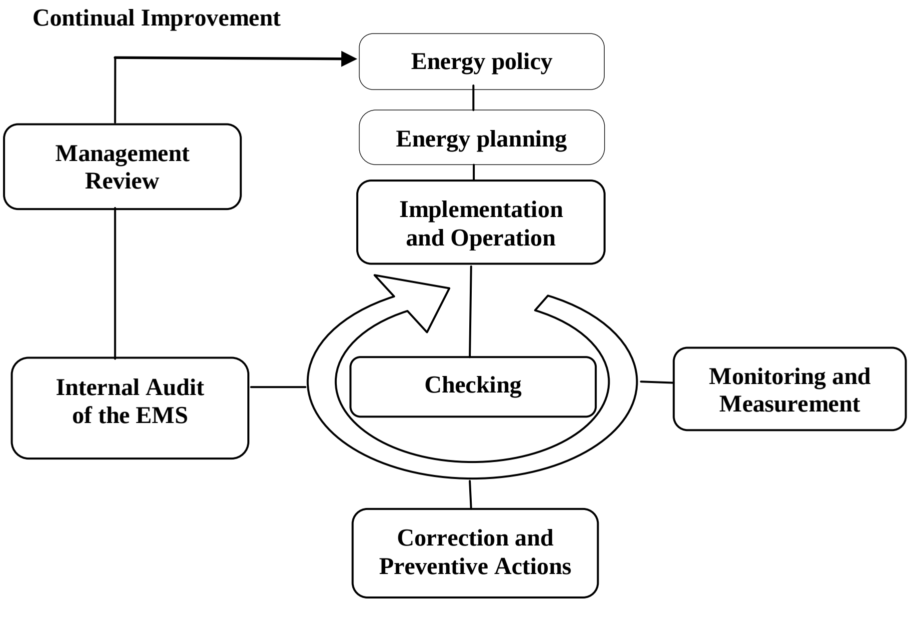

Fig. 1. Energy Management System Model

This survey covered more than 80 large industrial enterprises of Russia, engaged in energy sector, oil, gas, coal, metallurgical, extractive, chemical and petrochemical industries, as well as in transport and communication spheres.

The information about the share of companies under survey which implemented EMS, is given in the fig. 2.

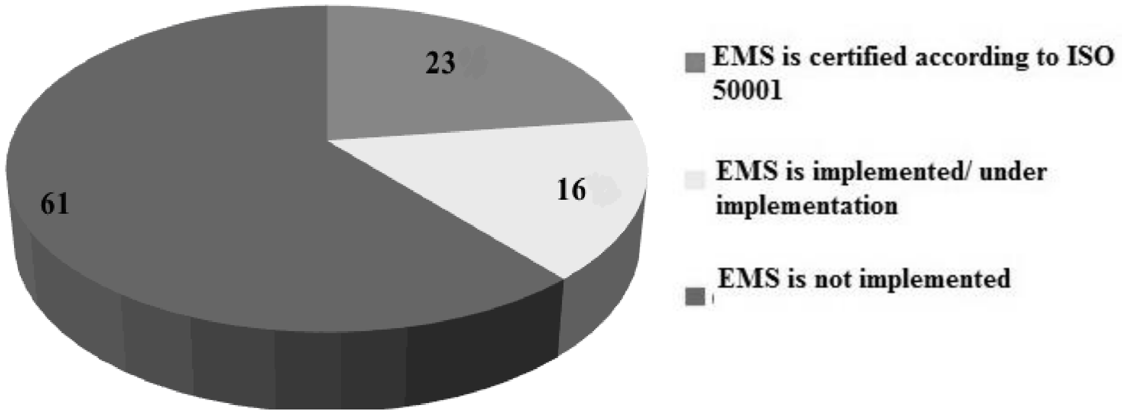

Fig. 2. The share of companies under survey which implemented EMS, %

As we can see, only 23 % of the companies surveyed implemented EMS. The most part of industrial companies, which are implementing EMS, is made up of big companies of energy, oil, gas, and coal industries. This can partly be explained by an increased attention to this issue of the Ministry of Energy as the federal supervising body.

All companies that had implemented EMS, developed energy policy, energy saving programme, and energy saving and EMS standards. In 70 % of companies, there are methods of assessment of activities to enhance energy efficiency.

In companies, which only observe legislation requirements, the energy policy was developed only in 7 % of cases, and the methods to assess efficiency of activities to enhance energy efficiency are developed in 10 % of companies. Enterprise energy saving standards are developed in one third of the companies, and every fifth organisation does not have any energy saving programme.

The results of the research allow concluding that the results of the mandatory energy survey are applied mostly in industrial companies, that implemented EMS, which is indicated by 100 % availability of energy saving programmes there.

In fuel and energy industry, 36 % of companies have already implemented EMS, and 19 % are either implementing or planning to implement by the end of 2017. This indicates that there is a high interest of the fuel and energy industry companies in a systematic approach to the problem of enhancing their energy efficiency.

In other branches of industry, EMS is implemented in 3 % of the companies, with 12 % planning to implement it in the near years.

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The assessment of efficiency of implementation of EMS was carried out by experts by giving points for every criterion. At the same time, the significance of the influence of the indicator on the overall efficiency of energy saving activities and enhancing energy efficiency was determined. After the assessment, the efficiency rating was made, which indicates efficiency or inefficiency of implementation of EMS in a company.

Then, the companies were arranged by their points in %, which can be seen in the fig. 3.

The results of the study showed that in the process of energy efficiency management many companies underwent the energy survey, determined their further goals and objectives in energy saving and energy efficiency activities, conducted monitoring of indicators and highlighted those with the help of which the company may achieve increase in energy efficiency with minimal efforts and lowest investments (the performance ratio lies within 40–67 %).

Some companies went even further and appointed energy efficiency and saving supervisors, introduced key factors of energy efficiency, began energy efficiency training and raising awareness of energy saving among the personnel, realising mid-term activities, consisting in energy efficiency enhancement (the performance ratio lies within 67–90 %).

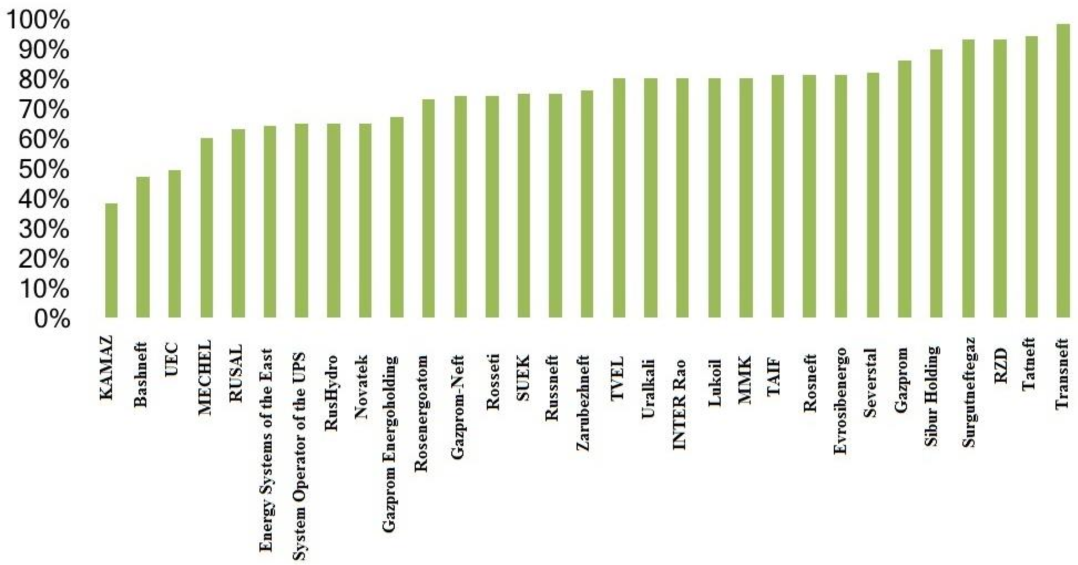

Fig. 3. Performance ratio of the companies under survey, %

During the survey, the evaluation summary of efficiency of functioning of EMS (fig. 4) was carried out, with the help of complex information analysis by chosen criteria of the energy management: fuel and power resources economy (%), the share of costs for energy saving measures from total costs of fuel and energy resources (%), the share of costs for fuel and energy resources in the cost of production compared with the base year.

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Besides, the complex performance ratio analysis of implementation and functioning of EMS in the companies (fig. 5) was made.

The high results of the evaluation summary of performance ratio and efficiency of EMS of the companies were shown by Transneft, Sibur Holding and Rosseti, which implemented EMS.

The analysis of the changes in a company followed by implementation of EMS demonstrates significant effects, that were achieved with the implementation of EMS and its elements. For instance, in Transneft the improvement of personnel discipline as well as planning procedures were detected.

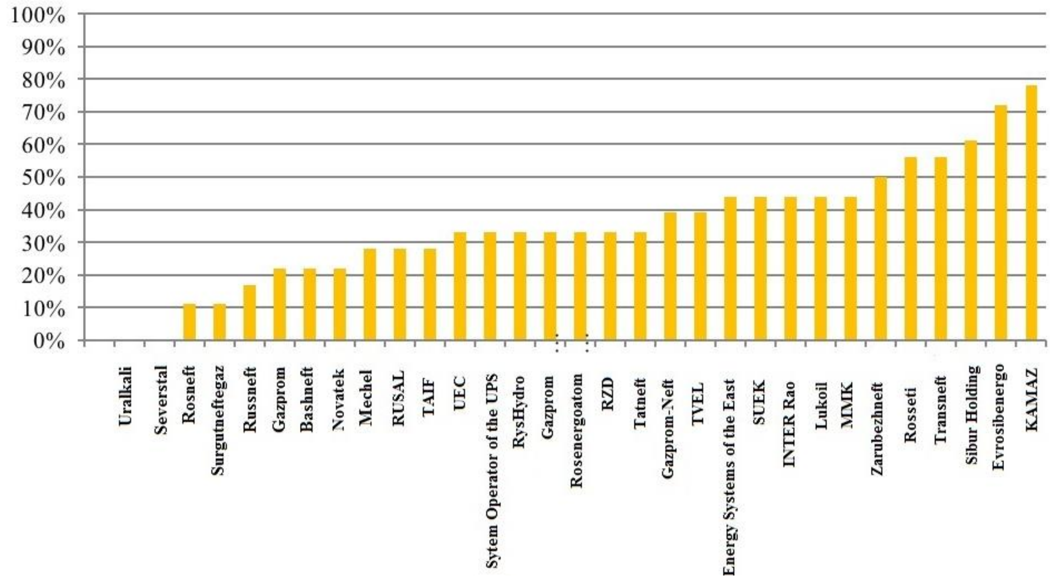

Fig. 4. Evaluation summary of EMS efficiency in companies, %

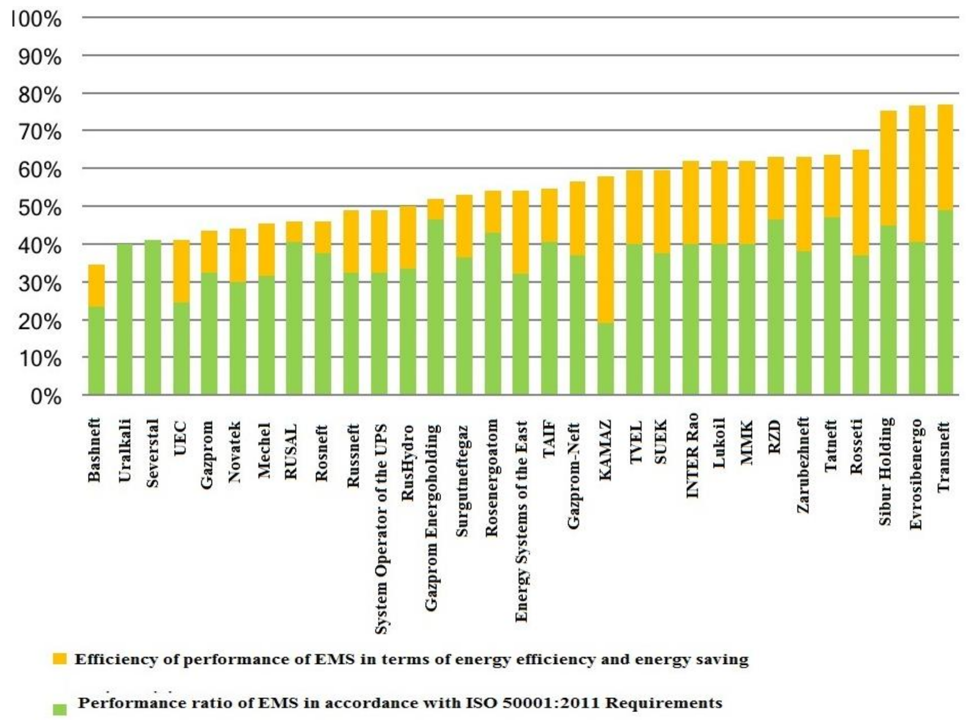

Fig. 5. Evaluation summary of performance ratio and efficiency of EMS in the companies, %

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In Sibur Holding the generation of energy saving ideas and reduction of project realisation terms were detected. The implementation of a new energy efficient equipment enabled increasing safety, reliability of nuclear power plant systems, and the convenience of their maintenance and repair, which were noted in Rosenergoatom. In TVEL, the consumption of fuel and power resources were successfully reduced by virtue of more energy efficient materials and equipment.

In some enterprises, an increase of transparency of formation of expenditures for fuel and power resources were noted, which enabled, for instance in Rosseti, planning realisation of high energy efficient activities aimed at energy saving.

In RZhD there was a significant rise of performance ratio of energy saving activities. Also, the increase in the personnel involvement, implementation of best practices on railways, reduction of terms, and rational choice of places of implementation of energy saving technologies were noted.

Lukoil implemented Real Time Database (RTD), which now enables conducting real time objective assessment of fuel and power resources consumption by the personnel and taking prompt measures to reduce the consumption.

The qualitative result of the implementation of EMS in Surgutneftegaz is an increase in promptness of decision making, arrangement of management procedures in energy saving and enhancement of transparency of these procedures, organisation of the system of continuous energy audit of basic technological processes of oil extraction.

Despite a significant level of popularity of EMS in Russia’s industrial companies, a range of companies face challenging factors which make it difficult for them to realise activities of development and implementation of EMS [11]. Among these factors there are:

- poor elaboration of the methodological base for justification of feasibility of energy saving and energy efficiency increasing activities;
- poor financial support of activities aimed at energy saving and energy efficiency increasing;
- lack of awareness of the efficiency and performance of EMS among the administration and personnel of the companies;
- lack of motivation of the administration and personnel of the companies to develop and implement EMS;
- lack of information about the companies providing services (energy analysis, recommendation on energy efficient activities, audit and automation) in development and implementation of EMS.

From the given theoretical analysis, it is obvious that EMS is one of the functional systems of industrial enterprise management. The implementation of EMS is an activity aimed at planning, organisation, and control of FPR utilisa-

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tion in enterprises and motivation of energy saving on the basis of establishment of interrelating elements of the energy infrastructure and the personnel.

Methods

For sustainable management of energy efficiency, it is necessary to implement EMS, which is one of the subsystems of the overall system of enterprise management, thus connecting in one complex unit the strategic goals of the company and development of the energy policy, the energy audit and the energy resources accounting system, training personnel in energy saving, formation, realisation and monitoring of the energy saving programme and automation of energy saving and energy efficiency increasing activities.

Strategic Goals of the Company and Development of Energy Policy

The most crucial stage in organisation of EMS is the formation of the energy policy of the enterprise [12]. The energy policy is a system of monitoring and prognosis of the energy situation, formation and continuous improvement of the organisational, economic and legal mechanisms, which ensure reliable power supply and FPR rational utilisation.

The management practice shows that one of the main directions in the development of the energy policy is the formation of the fuel and energy balance as a tool for planning, controlling and forecasting changes in the conditions of the management of an industrial enterprise. In order to achieve the planned indicators, enterprises also need to use dynamic methods of energy consumption analysis, which allow tracing negative tendencies and eliminating them in the process of implementation of the energy consumption strategy.

While developing the energy policy and defining the strategic goals of an industrial company, special attention should be given to the following:

It is obligatory to find out the energy saving sources reserves, which belong to technological sphere, management of human resources, the sphere of ecological decisions in production process and others. It is also obligatory to develop methods to find reserves of energy saving.

The problems of implementation of EMS should be raised to the level of strategic analysis of the internal and external environment, in order to find fundamental problems of energy saving in enterprises, which belong to infrastructure, principles of work, general technological processes in enterprises. The fundamental problems are crucial for development of long-term investment plans in the enterprise.

In order to improve EMS it is obligatory to develop internal scientific and technical, and organisational and management structures, responsible for planning of innovative decisions in energy saving.

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Training Personnel in Energy Saving and Energy Efficiency Increasing

An exceptional role in EMS is played by the personnel of the enterprise, who take the energy efficient initiatives and are the basis for formation of the internal expertise base of the energy management, and fulfill the innovative function. To improve efficiency of the work in energy saving, the enterprises conduct a multistage training of their personnel and use external intellectual resources.

The implementation of EMS requires introduction of all-round changes at all levels of the management of enterprise, beginning from the top management, at the level of strategy and structure of management, and ending with operational one, at the level of final administrators [13].

In the first place, the implementation of EMS should be initiated by the top management of an industrial enterprise. From the top management of the industrial company, it is required to appoint the person responsible for the introduction and implementation of EMS, with the authority and the required resources. Then, the changes of the organisational structure should be made, and a special body should be established (for instance, Energy Management Department, EMD).

The EMD encompasses the following major functions [14]:

- energy audit of industrial and auxiliary sections of the enterprise;
- development, introduction and supervision of projects of energy saving and energy efficiency;
- management of energy service contracts;
- support of the processes of purchasing energy resources;
- fulfillment of EMS programmes control;
- training the enterprise personnel;
- continuous search for key solutions.

The importance of realisation of EMS within the explained management structure is justified by its uniqueness in terms of involvement of all bodies and departments of the company in the realisation of the project, and integration of the processes of management, which are focused on increasing efficiency of energy consumption at all management levels. This enables quick deep organisational changes into the structure at all levels of the management of the company.

Energy Audit and Energy Resources Accounting System

The control of performance of EMS being implemented is carried out at the expense implementation of efficient energy resources accounting systems, management of energy consumption, and regular energy audit. The last one is a

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software collection and analysis of information on sources, energy consumers, its ways of conversion, and its irrevocable losses.

When conducting the energy audit, it is obligatory to determine the general structure of energy consumption, directions and efficiency of utilisation of energy for further finding out the problems and the reasons for their emergence. The determination of the general structure of the energy consumption should begin with determination of basic elements of fuel and energy balance, sources of loss of various kinds of FPR. The losses are determined as inefficiency of technological processes, and the lack of rational approaches to organisation of works in the energy intense industry.

The basis of the audit becomes the establishment of qualitative and quantitative criterion values, reflected in the system of standards of the energy management. The audit enables efficient reducing energy expenditures in a short-term period and determining basic directions of energy savings in the future.

Formation, Realisation and Monitoring of the Energy Saving Programme, Automation of Activities of Energy Saving and Energy Efficiency Increasing

When forming the energy saving programme in the enterprise with high energy intensity production, the reserves for optimisation can be found in increasing energy efficiency of production processes and, in cases when different energy carriers are used, in the alteration of the structure of their consumption [15]. Increasing energy efficiency is feasible in the first place at the expense of implementation of more economical technologies in the major technological processes, and, in the second place, at the expense of application of general measures of energy saving. This kind of optimisation fosters reduction of costs in the long-term period and, subsequently, enhancement of competitiveness of the enterprise.

On the other side, on a national scale, the task to encourage enterprises' energy saving is justified by the fact that, firstly, the reduction of costs for production leads to increase of competitiveness of this production in the world market, which can contribute to the national economy growth. Secondly, the reserves of conventional energy resources are gradually exhausted. Thirdly, there is a negative impact of burning carbon-containing fuel on the environment

One of the crucial tasks of the state in this sphere is to establish a well-structured normative base of energy saving.

Currently, many enterprises are tailoring their internal energy saving business processes to international standards, in order to keep a high level of competitiveness and ensure their positions in the markets. The management of business processes are the management of energy saving, investment projects, financial management in the energy sector and management of the personnel's motivation to improve energy efficiency indicators. All these processes directly

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relate to basic production processes and determine their energy efficiency in the long-term future. Among the supporting business processes there are different kinds of repairs of equipment of energy sector, resource supply, operational production control and control of financial results of energy saving programmes realised in the enterprise.

In the future, it is necessary to automate not only the process of collecting, accounting and analysing the energy consumption data, but also adjusting energy saving programmes in accordance with the changes in fuel and energy balance of the enterprise, identifying energy saving reserves, developing innovative approaches to energy saving.

When realising these methods of management, the best results can be achieved in increasing energy efficiency of enterprises. Thus, the performance ratio of the enterprises, that implemented EMS in accordance with ISO 50001:2011, can reach 98 %.

Final Remarks

By the present time, due to rising relevance of energy saving related problems caused by significant rise of energy resources' prices, the enterprises have developed traditional approaches to the energy management. The major ones reflect separate directions of energy saving which are further connected in one system with the help of strategic energy management.

The basic traditional approach is the formation of operational management of processes, modes of energy saving by virtue of technical control of production parameters, establishment of standards within the energy basis and formulation of the principles of motivation of the enterprise personnel. Traditional approaches are significant contributors, since they ensure the initial setting of the task of energy saving, demand attention of the administration of the company to the establishment of the unified system.

The development of traditional approaches leads to formation of the systematic idea of EMS as a combination of elements making up the basis of regular business processes with a developed system of training and motivation of the personnel.

The tendency that justifies transition to the systematic energy management, is a transition of the enterprise from one-time projects of investment in the energy infrastructure to construction of cyclic processes of development and implementation of organisational and technical measures in this sphere [14].

The model of EMS should function in the enterprise on the basis of the continuous cycle, the stages of which are given in the fig. 6. The cyclic fulfillment of these stages will enable implementing EMS on a longer-term basis, which will increase its efficiency.

Considering the suggested recommendations will enable any industrial enterprise to implement the management changes, allowing it to reduce energy ex-

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penditures on the systematic and long-term basis, which will significantly increase its energy efficiency.

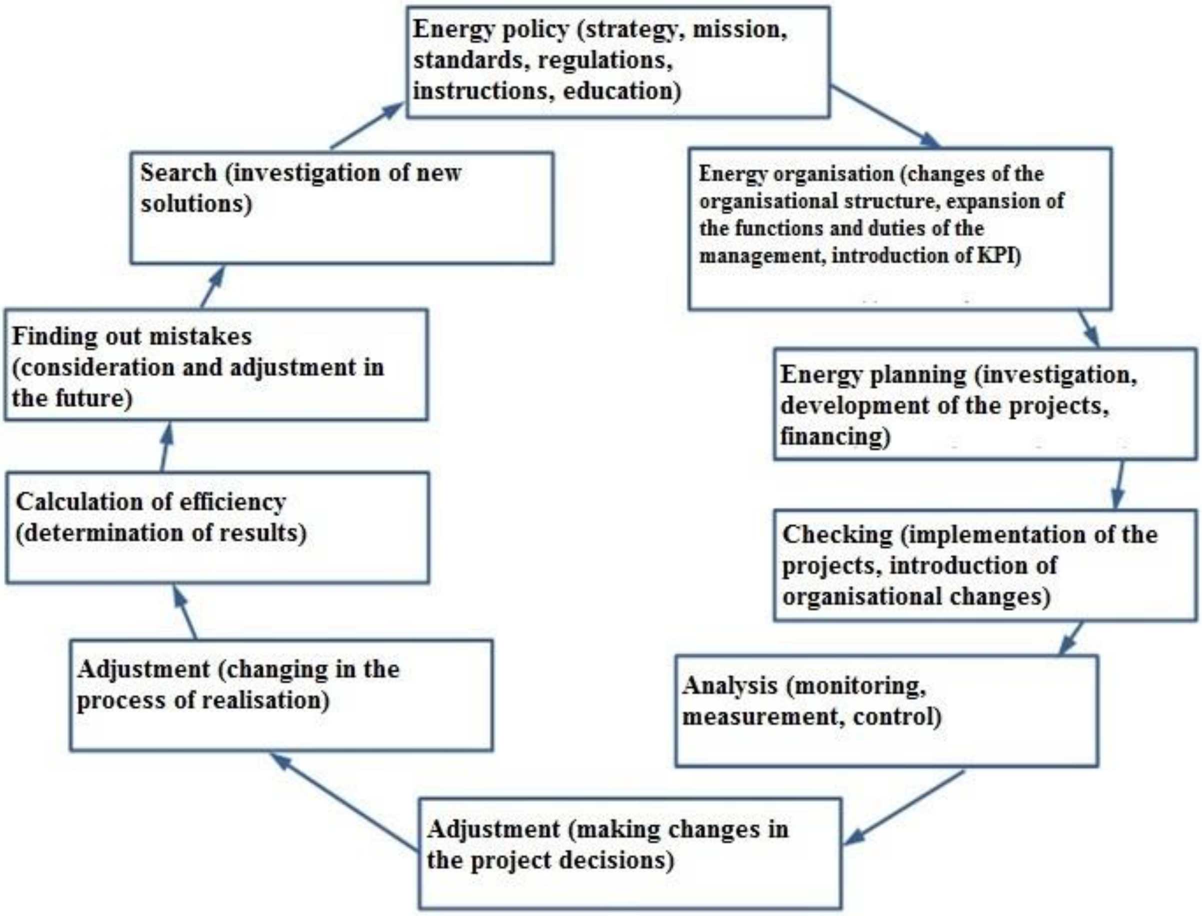

Fig. 6. EMS-model

EMS of the organisation is, without any doubt, an innovative decision, which is connected with the modernisation of the existing methods of management and psychology of management of energy consumption and energy expenditures.

In order to increase the quality of realisation of EMS in Russian industrial companies, it is necessary to implement the following measures:

- monitoring, analysis, popularisation and dissemination of best practices of the implementation of EMS on the basis of ISO 50001:2011;
- improvement of the methodological base of EMS and normative and technical base;
- expansion of practices of application of benchmarking for formation of goals and indicators of increasing energy efficiency and energy saving;
- development of professional and educational standards in the sphere the energy management;

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- provision of energy management related education and qualification upgrade of specialists of industrial companies;
- preparation and acceptance of mid-term plans and programmes of implementation of EMS by companies;
- expansion of supporting measures and stimulation of companies to implement EMS;
- development of the system of voluntary certification in the sphere of the energy management;
- formation and implementation of the unified register of the authorised individuals and legal entities, providing services in the energy management;
- formation and maintenance of the unified register of the companies that confirmed their implementing EMS.

Conclusion

Thus, upon realising the above-mentioned measures, the conditions for transition to the large-scale implementation of EMS will be provided. This, in its turn, will foster realisation of the national policy in the sphere of energy saving and energy efficiency.

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TRAINING OF SPECIALISTS AND DEVELOPMENT OF DESIGN REGULATORY FRAMEWORK FOR RUSSIAN MAGNETIC LEVITATION TRANSPORT SYSTEMS

The article deals with the issues of training of specialists and development of design regulatory framework for Russia's magnetic levitation transport systems.

Introduction: The development of maglev technologies in Russia requires solving the task of training specialists and developing the design regulatory framework for the magnetic levitation transport systems (MLTS). The MLTS related specific issues, namely traction, levitation, lateral stabilisation, power supply systems as well as overall safety, should receive special attention.

Analysis: The maglev transport technology is a further development of a conventional "wheel-track" technology, employing the linear motor and the magnetic levitation system (electromagnetic, electrodynamic, the permanent magnets-based system, and combined types). Each type of MLTS possesses its advantages and limitations, which points at the necessity to justify the choice of an optimal technology.

A crucial issue is to choose (develop) a linear motor for MLTS on the basis of the four related aspects: electromagnetic, thermal, mechanical, and the cost related one.

Another significant issue is the overall safety provision of MLTS. The elaboration of the quality management system should be carried out in accordance with all stages of the life cycle of the wheel-track transport, which is specified in EN 50126, EN 50128, and EN 50129.

Methodology: The methodological base of training specialists and developing the design regulatory framework should become a systematic approach. The necessity of the application of this approach lies in the variety and complexity of physical processes of MLTS. The development of the project and working documentation of the design and construction of MLTS in the territory of Russia should be carried out in accordance with the active Russian legislation, which specifies the application of Special Technical Regulations for new technical systems.

Conclusion: As of today, it is reasonable to develop the training of specialists for MLTS on the basis of the qualification upgrade and professional retraining programmes of the engineering staff, who already possess the fundamental railway education. All the necessary expertise and competences are available at Emperor Alexander I St. Petersburg State Transport University. For many years, the university's specialists have been working on the development of the maglev technologies in Russia both on the basis of their own researches and on the study and generalisation of the national and international experience. They have also been developing the projects of the design regulatory framework for future MLTS.

Keywords: Magnetic levitation transport systems, training of specialists, design regulatory framework.

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ПОДГОТОВКА СПЕЦИАЛИСТОВ И РАЗРАБОТКА НОРМАТИВНОЙ БАЗЫ ПРОЕКТИРОВАНИЯ МАГНИТОЛЕВИТАЦИОННЫХ ТРАНСПОРТНЫХ СИСТЕМ В РОССИИ

Аннотация. Рассматриваются вопросы подготовки специалистов и разработки нормативной базы проектирования магнитолевитационных транспортных систем (МЛТС) в России.

Введение: Развитие магнитолевитационных транспортных технологий в России требует подготовить специалистов и разработать нормативную базу проектирования МЛТС, при этом особое внимание следует обратить на специфичные для МЛТС вопросы, связанные с системами тяги, левитации, боковой стабилизации, электроснабжения, а также с обеспечением комплексной безопасности.

Анализ: Магнитолевитационная транспортная технология представляет собой развитие традиционной технологии «колесо – рельс» на основе использования линейного тягового двигателя и системы магнитной левитации (электромагнитной, электродинамической, на основе постоянных магнитов, комбинированной). Разные типы МЛТС имеют свои преимущества и ограничения, поэтому необходимо обосновать выбор оптимальной технологии.

Важным вопросом является выбор (разработка) линейных тяговых двигателей для МЛТС на основе согласованного формирования четырех моделей: электромагнитной, тепловой, механической, стоимостной.

Также важно обеспечить комплексную безопасность МЛТС: прикладное наполнение систем менеджмента комплексной безопасности должно соответствовать этапам жизненного цикла систем колейного транспорта, изложенным в стандартах EN 50126, EN 50128 и EN 50129.

Методы: Методологической основой подготовки специалистов и разработки нормативной базы должен стать системный подход, который определяется разнообразием и сложностью физических процессов МЛТС. Проектная и рабочая документация на проектирование и строительство МЛТС на территории России должна составляться в соответствии с действующим российским законодательством, предусматривающим применение специальных технических условий для новых технических систем.

Выводы: Сегодня специалистов для МЛТС целесообразно готовить на основе программ переподготовки и повышения квалификации инженерных кадров, имеющих базовое железнодорожное образование. Всеми необходимыми компетенциями для разработки и реализации таких образовательных программ обладает Петербургский госу-

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дарственный университет путей сообщения Императора Александра I: сотрудники университета на протяжении многих лет работают над магнитолевитационными транспортными технологиями в России на основе как собственных исследований, так и обобщения отечественного и мирового опыта, создают проекты нормативных технических документов для будущих МЛТС.

Ключевые слова: магнитолевитационные транспортные системы, подготовка специалистов, нормативная база проектирования.

Introduction

The magnetic levitation technology as the next stage of the innovative development of the conventional railway transport requires solving the task of training the specialists and elaborating the design regulatory framework for the magnetic levitation transport systems (MLTS) that will encompass a wide range of aspects:

- infrastructure;
- rolling stock;
- systems of traction, levitation and lateral stabilisation;
- electric power supply;
- organisation and control of traffic;
- overall transport security provision;
- passenger service and logistics;
- economics, including the issues of financial and technical support of construction and operation, and the investment justification issues (feasibility studies);
- personnel management, including the psychology related issues (informational and psychological security);
- engineering surveys;
- methodology of design, including RAMS (Reliability, Availability, Maintainability, Safety) / LLC (Life Cycle Cost) issues;
- organisation of construction;
- business management, including the issues of quality and security management.

The MLTS related specific issues, namely traction, levitation, lateral stabilisation, power supply systems as well as overall safety, should receive special attention.

Analysis

The magnetic levitation transport technology represents a further development of the conventional "wheel-track" technology, but with the linear motor and the system of magnetic levitation employed. We can point out three basic types of this technology:

- the electromagnetic suspension type (EMS) – the attractive force (fig. 1a);
- the electrodynamic suspension type (EDS) – the repulsive force (fig. 1b);
- the permanent magnets-based suspension (fig. 1c).

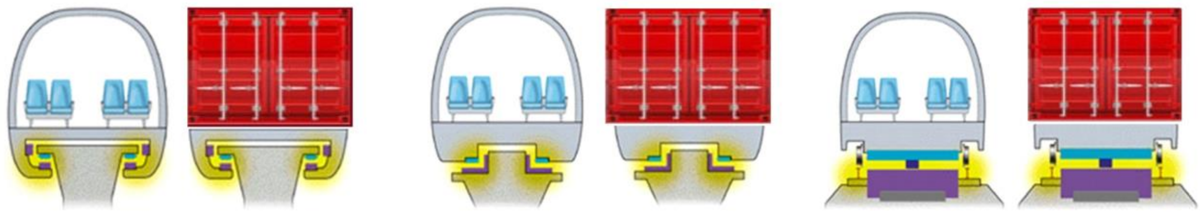

Fig. 1. The basic types of the maglev transport technology

The MLTS has the following key competitive advantages:

- high speed of passenger and freight transportation;
- high carrying capacity owing to high level of automation ("transport conveyor");
- independence from external conditions (other means of transport's traffic and weather conditions);
- high adaptability to terrain features, urban areas (unlike railway transport);
- low power consumption with the application of the permanent magnets (owing to absence of moving units and gears);
- continuous improvement of the technology and reduction of the construction costs;
- high sustainability ratios (low levels of noise, vibration and dust, urban environment compatibility), absence of the barrier effect, which is a characteristic feature of railways and roads.

As of today, the world operates several passenger MLTS predominantly in the Eastern Asia states: China (Shanghai, Changsha, Beijing), Japan (Nagoya, Yamanashi), the Republic of Korea (Incheon). The realised MLTS projects are also present in Germany, the USA and other states. The USSR conducted MLTS tests too.

Different types of MLTS possess their own advantages and limitations (see the table below) which indicates the necessity to develop an optimal technology.

Alongside the choice (development) of the levitation and lateral stabilisation technology (see the table below), there is also a crucial issue of the choice (development) of linear motors for MLTS on the basis of the four conjoined aspects:

- electromagnetic;
- thermal;
- mechanical;
- cost related.

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The main advantages and limitations of different types of MLTS

MLTS type	Advantages	Limitations
EMS	1) The low cost of materials for the flyovers (steel); 2) the application of the practice-proven methods of operation and the components available in the market; the technology is well tested and used	1) High losses in the actuating coil; 2) non-linear effects and eddy currents; 3) small gap (does not exceed 20 mm, as a rule) resulting in the increased requirements (but not for railway transport) for the accurate manufacture and assembling of the flyover and rolling stock (with the adverse weather conditions considered)
EDS (with the superconducting magnets employed)	1) Insignificant losses in the actuating coil enable the application of high voltage currents and achieve magnetic field of high strength; 2) the large gap makes the rolling stock less sensitive to irregularities of the track	1) High consumption of liquid nitrogen (helium) for the cooling system; 2) very low dampening of oscillations; 3) high starting speed (approximately 100 km/h): with the speeds below critical level the additional suspension is required; 4) additional equipment for cryostats
The suspension with the permanent magnets employed	1) In case of large volumes of production the cost of permanent magnets does not exceed the production of steel; 2) simple configuration and low technical maintenance costs	1) The attractive and repulsive poles static requires additional lateral stabilisation; 2) reduction of the magnetic field force in case the magnets are heated (for instance, in case of the air temperature rises); 3) the result of the reduction of the magnetic field force may become the decrease of the levitation gap with the arising necessity to ensure it with the help of additional measures
The combined suspension	Different options of design with the use of electromagnets, permanent magnets, different types of linear motors (synchronous, asynchronous, etc.) are achievable	

The analysis of the today's approaches to the design of linear motors [1, 2], shows that justification of their key indices (traction, mass, power consumption and cost) actually consists in the task to thoroughly optimise these indices by many technical properties (fig. 2).

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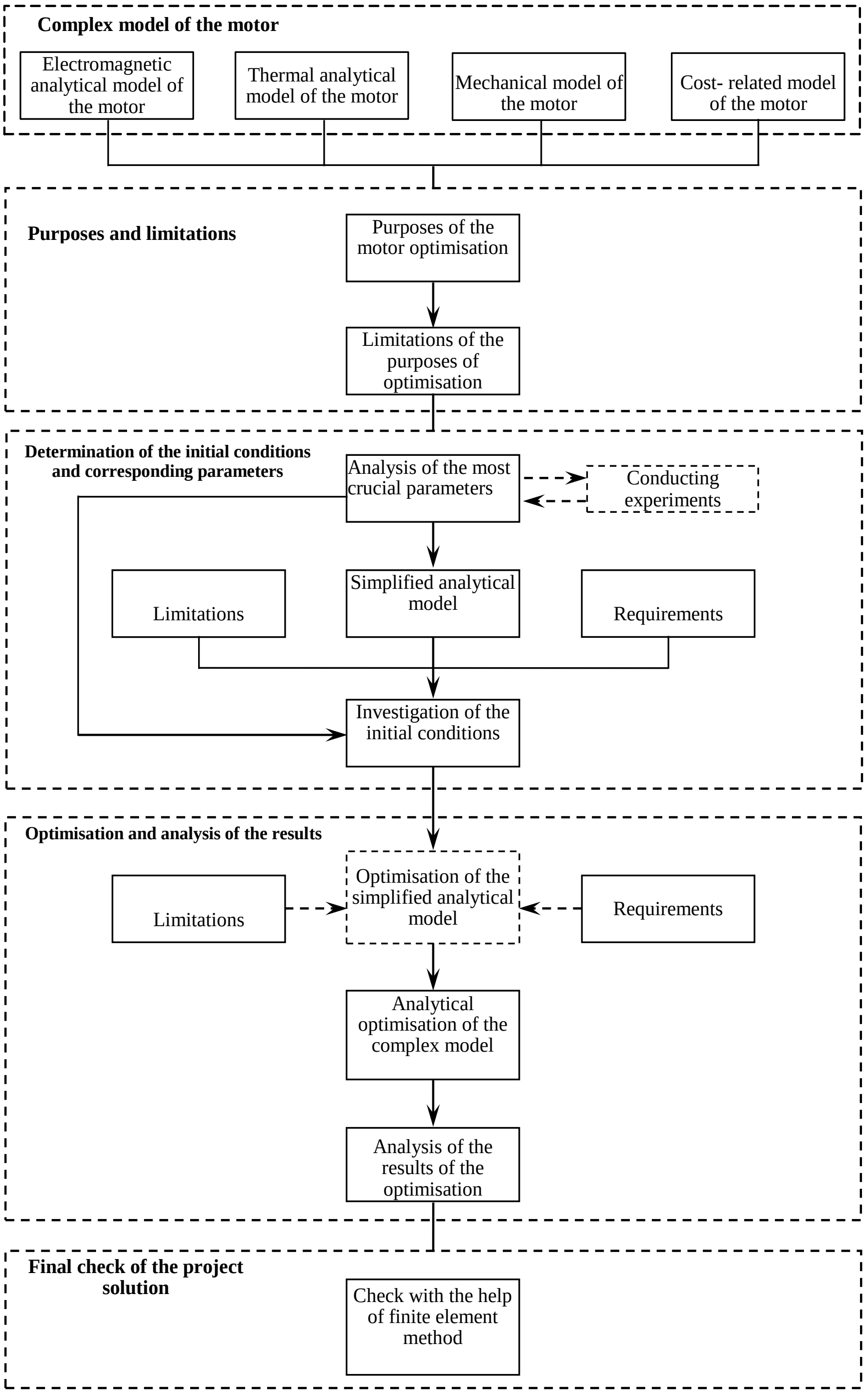

Fig. 2. The linear motor optimisation scheme [2]

The existing in Russia practice of the development of the design solutions for linear motors basically aims at direct calculations of their tractions properties with their subsequent finalisation on the stands or in the testing grounds. The widely used finite element method is useful for calculation of the magnetic flux at any point and, using this principle, for calculation of the traction properties of the motor (the solution of the direct task of the motor efficiency assessment). However, this method is labour-intensive and it does not provide an efficient

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solution of the reverse task, that is the multiple repetition of the direct task in the optimisation cycles.

The alternative to the finite element method is the modelling of the magnetic fluxes in the linear motor (including for the permanent magnets) by interpolation between simple special cases (for instance, the case of the magnetic flux in the linear conductor with the current). The obtained analytical expressions thereby may be actively used for solving both direct and reverse tasks of the linear motor efficiency assessment.

In general, the linear motor design process should have the following stages:

1) the determination of the requirements to the parameters of the motor and the purposes of the design;

2) the determination of the possible design solutions by means of which the requirements to the motors are realised. For instance, the application of *m* technologies of traction (synchronous motors, a long or a short stator, permanent magnets, etc);

3) the first option, based upon the application limitations. In the result of this option the number of possible design solutions decreases to *n* ($n<m$);

4) the elaboration of the models of the motor in accordance with the purposes of the project. At the same time, the models should include:

- a mechanical model for description of the motor dynamics;
- a thermal model for description of the heat transfer in the motor;
- an electromagnetic model for determination of electrical and magnetic values and forces (attraction and repulsion);
- a cost model for determination of the cost of the motor at each stage of its life cycle;

5) the design of *n* options of the motor, confirmation of the source data and limitations, and, if needed, the alteration of the limitations;

6) the sensitivity research of the parameters of the motor for all conditions of the application and all *n* options, and the choice of optimal parameters for each option;

7) the comparison of all *n* options;

8) the final choice of the motor using the key indices;

9) the acceptance of the project of the motor on the basis of the manufactured prototype or a model that uses that uses the finite element method;

10) the documentation of the final project.

The project solutions of the choice of the linear motors should be Pareto efficient by the following criteria:

- traction – power consumption;
- traction – mass of the active guideway structure;
- traction – mass of the motor’s moving part;
- traction – cost.

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Another important issue is to ensure the overall MLTS safety. The unified base for constituents of the overall security [3] is quality management systems, based upon ISO 9001 [4]. With the reference to the guided transport, they are as follows:

- ERA SMS (the Safety Management System of European Railway Agency) for traffic safety [5, 6];
- MODSafe (Modular Urban Transport Safety and Security Analysis) for transport safety (including traffic safety) [7], the systems based upon ISO 28001 [8] for supply chain security;
- the systems based upon the international standards OHSAS 18001 [9] and ISO 14001 [10] for occupational and environmental security respectively.

The applied filling of these management systems is carried out in accordance with the life cycle of the guided transport, specified in EN 50126 (IEC 62278 [11]), EN 50128 (IEC 62279 [12]) и EN 50129 (IEC 62425 [13]), as well as in IEC 60300-3-3 [14]. At the same time, regarding safety, the stage of the risk analysis has the crucial significance [15], which determines the risks in traffic safety, transport safety (protection against unlawful interference), occupational and environmental safety. Then the risk associated with them is assessed, and in case there is need to decrease this risk, the additional security functions are determined (fig. 3). With the reference to transport safety, at this stage the measures of pre-emptive (prevention), timely (prompt actions) and emergency (minimisation of damage) actions are taken against unlawful interference in accordance with the chosen model of behaviour of the potential intruder.

The measurement of risk that considers both accidental and systematic hazardous events (failures, malfunctions, breaches), is the Safety Integrity Levels (SILs), each of which stipulates a number of measures to be taken to mitigate the risks to the tolerable level.

As it was mentioned, while training specialists and elaborating the design regulatory framework for MLTS, special attention should be given to the specific maglev transport technologies related issues. The methodological framework for training specialists and developing the design regulations should become a systematic approach. The necessity of application of this approach is determined by a significant range and complexity of the physical processes in MLTS, and, consequently, by a high variety and complexity of engineering solutions required for a coordinated management of these processes. In other words, the complexity of the management of the MLTS creation processes should be no less than the complexity of the MLTS itself.

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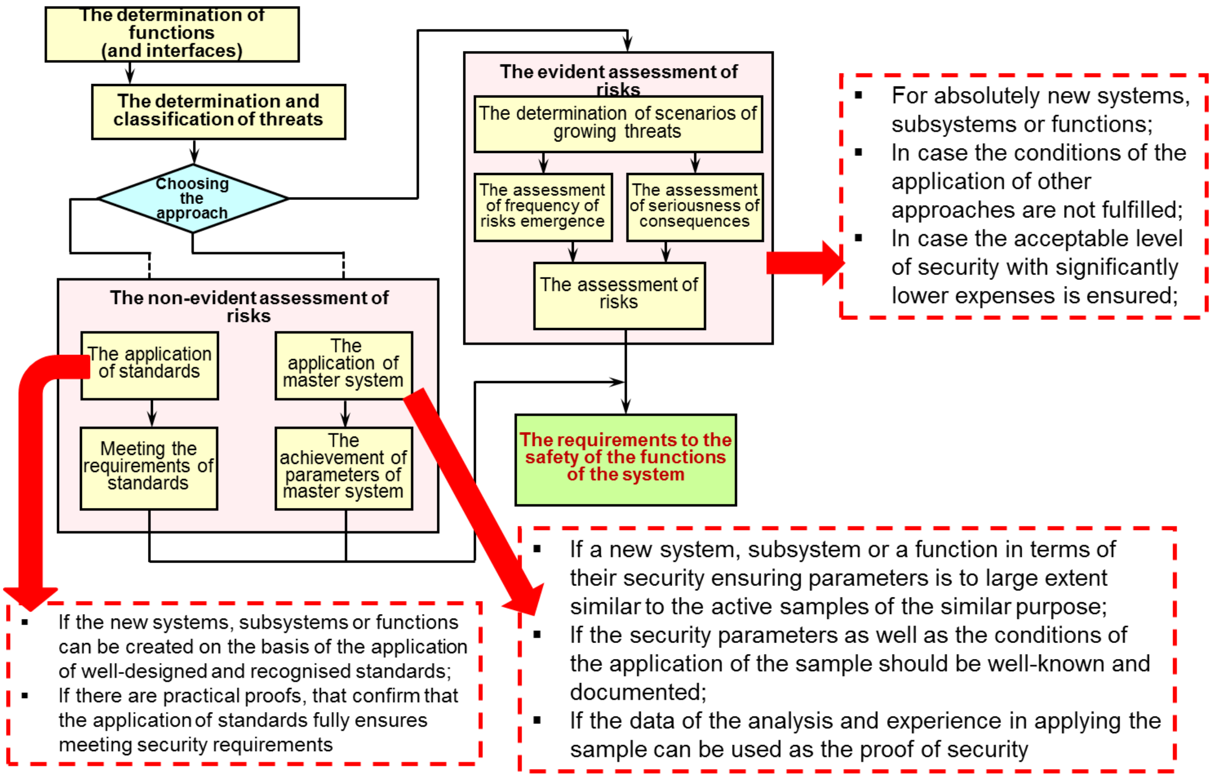

Fig. 3. Three approaches to the assessment of the risks for MLTS

The complexity of the systematic approach is determined by the constituents of the sphere for which it is to be applied:

- the necessity to analyse different combinations of the technologies of traction, levitation, lateral stabilisation and power supply;
- the specifics of dynamics of the 3D motion of the MLTS rolling stock. Such phenomena as yaw motion, pitching and rolling of the vehicle require taking corresponding measures for stabilisation and dampening;
- the complexity of the composition of the MLTS function and their hierarchy. There is need to elaborate a functional and structural model of the MLTS models;
- the mathematical apparatus of the analysis of the physical processes of the MLTS;
- the apparatus for mathematical modelling of the MLTS processes;
- the apparatus for natural modelling of the MLTS processes;
- the basic production of the MLTS components;
- the basic construction of the infrastructure objects of the MLTS;
- the environment of operation of the MLTS;
- the analysis of the risks associated with the MLTS;
- the organisational structure of design, construction and operation of the MLTS;
- the society's objective demand in the MLTS;

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- the society's subjective perception of the MLTS;
- the international level of the development of the MLTS.

As of today, it is relevant to develop the system of training specialists for MLTS on the basis of the qualification upgrade and retraining programmes for the engineers who possess the fundamental railway education (fig. 4).

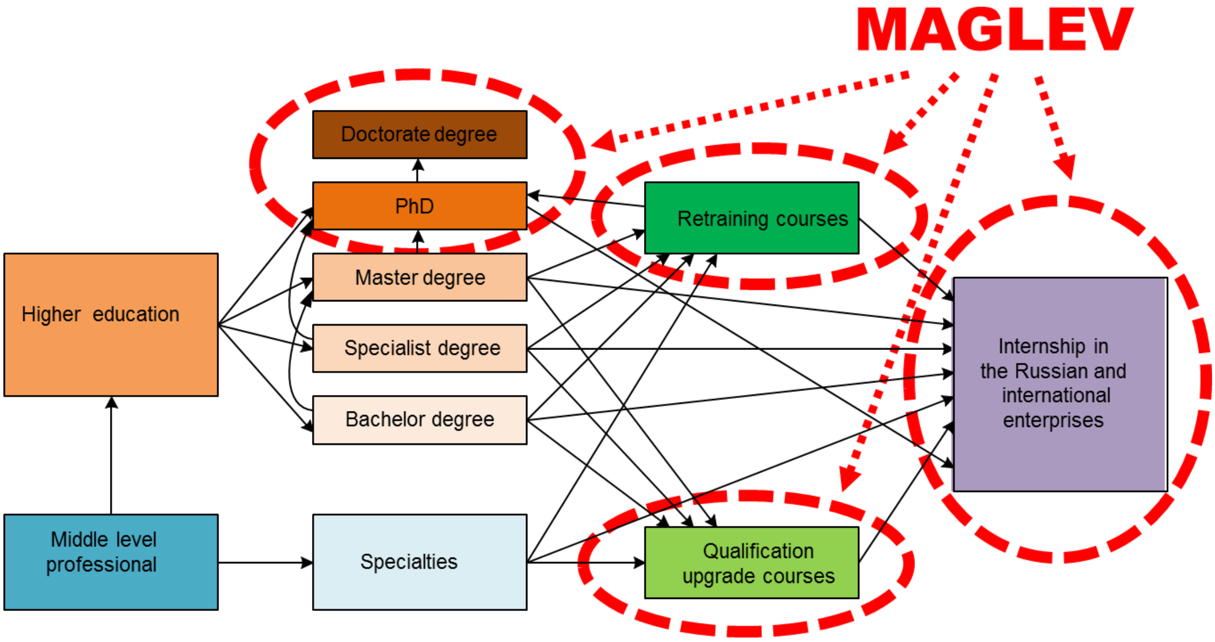

Fig. 4. Options of training specialists for the MLTS

All the necessary competences for the elaboration and realisation of such programmes are available at Emperor Alexander I St. Petersburg State Transport University. For many years, the university's specialists have been working on the development of the maglev technologies in Russia both on the basis of their own researches and on the study and generalisation of the national and international experience. In the specially established laboratory, they conduct laboratory (fig. 5a) and natural (fig. 5b) researches and develop the projects of the design regulatory framework for future MLTS.

The elaboration of the design and working documentation for design and construction of the MLTS in the territory of Russia should be carried out in accordance with the active legislation, namely, with the Order of the Government of the Russian Federation № 87 of February 16th, 2008 "On the composition of the sections of the design documentation and requirements to their contents" and other legislative and normative technical documents.

a b

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Fig. 5. A laboratory stand (a) and a test model (b) for research of the magnetic levitation transport technologies

Some subsystems and components of the MLTS are subject to the technical guidelines of the Eurasian Customs Union and the Russian Federation (in the first place, "On the safety of buildings and structures", and also "On the safety of machinery and equipment", "On the safety of the low-voltage equipment", "The electromagnetic compatibility of technical means", and others) and other supporting standards and set of rules (for instance, for maglev rolling stock it is possible to use the Preliminary National Standard PNST 24-2014 "The innovative railway rolling stock. The order of the development and approval for operation").

The Russia's legislation also stipulates the application of the Special Technical Regulations (*STU*), which are "the technical requirements in the sphere of security of the object of the major construction works, containing (referring to the specific object of the major construction works) additional safety requirements to the set or absent requirements, which reflect the features of the engineering surveys, design, construction, demolition of the object of the major construction works, and contain deviations from the set requirements" (in accordance with the Item 10 of the Article 1 of the Urban Planning Code of the Russian Federation № 190-FZ of December 29th, 2004, stating "the object of the major construction works – building, construction, facility, other objects, the construction of which is not finished <…>, except for temporary constructions, kiosks, canopies and other similar buildings"). STU are the basis of the terms of reference for design and elaboration of design documentation (developed by a special project organisation or a consortium of project organisations). The approval of STU is currently conducted by the Ministry of Construction Industry of Russia, more specifically by the specially organised Normative and Technical Board of the Ministry of Construction Industry, with the involvement of a group of experts the recommendations of which are made in the form of the corre-

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sponding expert's conclusion. The issues of development and approval of STU are determined by the following documents:

- the Order of the Ministry of Construction Industry of Russia № 248/pr of April 15th, 2016 "On the order of development and approval of Special Technical Regulations for the elaboration of the design documentation for the object of the major construction works";
- "Methodical recommendations "The order of arrangement of Special Technical Regulations for the elaboration of the design documentation for the object of the major construction works" (approved by decision of the Normative and Technical Board of the Ministry of Regional Development of Russia, Protocol № 1 of February 1st, 2011).

Thus, there should be developed a set of STU for the MLTS planned for design, construction and operation in a special section.

STU should contain a list of forced deviations from the requirements of the active normative documents, the explanation of these deviations, and measures to be taken to compensate these deviations. As the practice shows, such explanations of the norms in STU, including methods, may be made in the form of attachments to STU or listed in the Explanatory note for STU. STU does not allow duplicating norms of Russia's active documents. Such are norms should be provided with the corresponding links. In this regard, during the elaboration of STU for MLTS, a list of normative and technical documents of Russia and the Eurasian Customs Union should be developed, which would be applicable (fully or partially) for the design. At the same time, the STU could contain separate provisions contained in normative documents of other countries, provide that they correspond to Russia's legislation.

Conclusion

It is relevant to conduct training of the specialists for MLTS on the basis of the qualification upgrade and retraining programmes of the engineering personnel, possessing fundamental railway education. Emperor Alexander I St. Petersburg State Transport University possesses all required competences for the development and realisation of such programmes.

Regarding the development of the national design regulatory framework for the MLTS, the authors of this paper have developed a set of STU projects for the design of the MLTS to be further adapted to a specific freight or passenger transportation line:

- STU-1 – General requirements on design;
- STU-2 – Track;
- STU-3 – Base for the track, artificial structures and facilities, joints and crossings;
- STU-4 – Terminals, intermediate stations, maintenance buildings and facilities;

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- STU-5 – Traction and power supply systems;
- STU-6 – Operation control system;
- STU-7 – Electrical communication and warning systems;
- STU-8 – Rolling stock;
- STU-9 – Overall security system.

In parallel with the elaboration of STU, the works have been started to create a project of technical regulations on security of maglev transport and to form a list of standardisation documents supporting it. This list should appear as a result of:

- determination of the existing documents, the application of which is possible with their updating;
- determination of the existing documents, which may be used after being updated and reconsidered;
- determination of the documents, required to be elaborated.

Besides, the authors have prepared a structured English-Russian and Russian-English maglev transport definition dictionary for publishing. The dictionary contains terms, definitions and requirements in design, construction and operation of the MLTS and reflects the best international and national experience in this sphere. The dictionary may be the base for the first educational guidance on maglev transport.

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