ISSN 2949-0812 (ONLINE)
DOI 10.46684/2023.1
WWW.BRICSTRANSPORT.RU

BRICS TRANSPORT

International science and practice journal

Volume 2
Issue 1
2023

ISSN 2949-0812 (ONLINE)
DOI 10.46684/2023.1
WWW.BRICSTRANSPORT.RU

BRICS Transport

SCIENTIFIC AND PRACTICAL PEER-REVIEWED JOURNAL

Founded in 2022

Publication frequency: 4 issues per year

Volume 2

Issue 1

2023

Транспорт БРИКС

НАУЧНО-ПРАКТИЧЕСКИЙ РЕЦЕНЗИРУЕМЫЙ СЕТЕВОЙ ЖУРНАЛ

Основан в 2022 году

Выходит ежеквартально

Сквозной номер 2

Том 2

Выпуск 1

2023

BRICS Transport

SCIENTIFIC AND PRACTICAL PEER-REVIEWED JOURNAL

Journal's main thematic focus: scientific, technical, organizational, economic, environmental, legal issues, history, current state and development prospects of the BRICS countries' transport complex; interaction of the BRICS countries on issues of transport support and international cooperation, global transport systems, as well as on professional education for the transport industry and development of cooperation between educational institutions and transport enterprises from different countries.

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Digital version registration certificate:
Эл No. ФС77-82614 dated January 27, 2022.

Website journal: bricstransport.ru
E-mail: brics@umczdt.ru
Tel.: +7(495)739-00-30. add. 180
105082, Russia, Moscow, 71 Bakuninskaya st.

FOUNDERS

- Federal State Budgetary Educational Institution of Higher Education "Emperor Alexander I St. Petersburg State Transport University", 9 Moskovsky pr., St. Petersburg, 190031, Russian Federation
- Federal state budget establishment additional professional education "Educational and instructional center for railway transportation", 71 Bakuninskaya st., Moscow, 105082, Russian Federation

PUBLISHER

- Federal state budget establishment additional professional education "Educational and instructional center for railway transportation"

Signed for printing 30.03.2023.

Транспорт БРИКС

НАУЧНО-ПРАКТИЧЕСКИЙ РЕЦЕНЗИРУЕМЫЙ СЕТЕВОЙ ЖУРНАЛ

Основная тематическая направленность журнала: материалы о научно-технических, организационных, экономических, экологических, правовых проблемах, истории, состоянии и перспективах развития транспортного комплекса стран БРИКС; о взаимодействии стран БРИКС по вопросам транспортного обеспечения и сотрудничества с другими государствами, мировыми транспортными системами, а также о подготовке персонала всех уровней для транспортной отрасли и развитии в данной сфере сотрудничества образовательных учреждений и транспортных предприятий разных стран.

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Свидетельство о регистрации электронной версии: Эл №ФС77-82614 от 27 января 2022 г.

Сайт журнала: bricstransport.ru
E-mail: brics@umczdt.ru
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Подписано в печать 30.03.2023.

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Editorial article
UDC 327.3
doi: 10.46684/2023.1.1

Major milestones in the creation and development of BRIC – BRICS

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For citation: Kiselev I.P. Major milestones in the creation and development of BRIC – BRICS. *BRICS transport*. 2023;2(1):1. https://doi.org/10.46684/2023.1.1.

Редакционная статья

Основные вехи создания и развития БРИК – БРИКС

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Для цитирования: *Киселев И.П.* Основные вехи создания и развития БРИК – БРИКС // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 1. https://doi.org/10.46684/2023.1.1.

Originally, the term — an acronym BRIC, referred to a group of four rapidly developing countries, including Brazil, Russia, India and China, with the most dynamic GDP growth, which, according to some world expert economists, have become able to challenge the economic power of the G7 countries (Group of Seven) and will collectively dominate the global economy in 2050. These countries have over 25 % of the world's land mass, they have about 40 % of the population at the time, and they have a combined gross domestic product (GDP) of $15.435 trillion ($). In almost every comparison they would be the largest global entity.

In September 2006 in New York, during the 61st session of the UN General Assembly, the first meeting of the foreign ministers of the four countries was held, where the idea of institutionalizing their relations was outlined.

The BRIC countries' leaders met for the first time on July 9, 2008 in Toyako Onsen, Hokkaido, Japan, following the G8 summit. Brazilian President Luiz Inácio Lula da Silva, Russian President Dmitry Medvedev, Indian Prime Minister Manmohan Singh and Chinese President Hu Jintao participated in the meeting in the Japanese city. They agreed to hold a full-scale summit of the BRIC heads of state in 2009.

The first BRIC forum was organized on June 16, 2009, in Ekaterinburg, Russia. The same leaders represented their countries there as in Japan in 2006. The focus of the summit was the improvement of the global economic situation and the reform of financial institutions. They discussed how the four countries could improve cooperation in the future and participate more actively in world affairs. The BRIC countries announced the necessity of finding ways to define a new global reserve currency — diverse, stable and predictable, although the published statement did not yet contain a direct criticism of the de facto dominance of the U.S. dollar in the world. The next meeting of the BRIC heads of state was scheduled to take place in Brazil in 2010, and it was held in the capital Brasil on April 15–16, 2010, with the participation of the same national leaders.

At the end of the summit it was reported about the signing of several interstate agreements, and the most important issues raised: overcoming the consequences of the crisis, and the creation of a new financial order, including the right to a larger influence of the four BRIC states in international organizations such as the World Bank and the International Monetary Fund.

In 2010, the Republic of South Africa expressed its desire to join the BRIC countries. In August of that year the process of its admission to the group was launched, which resulted in a formal decision on December 24, 2010. In April 2011, South Africa, represented by President Jacob Gedleyihlekisa Zuma, participated as a full member in the 2011 BRICS summit in the Chinese resort city of Sanya (Sanya). The group was renamed BRICS, where the "S" stands for South Africa.

It is interesting that the media noted that the proximity of the spelling and pronunciation of the acronym for BRICS to the English word "bricks" creates a positive, constructive image of an organization determined for the future.

BRICS summits are held annually, rotating in each country. At each summit, the group elects one of its country leaders as temporary chairman of BRICS.

The BRICS group's activities were affected by the COVID-19 pandemic in terms of the reduction of face-to-face contacts between BRICS politicians, but it only made it more difficult to resolve current issues without disrupting the general progress of the group's activities. For example, the XII BRICS summit in St. Petersburg, scheduled for July 21–23, was held via videoconference on November 17, 2020, chaired by Russian President Vladimir V. Putin, the President of the Russian Federation.

The last XIV Summit of the BRICS was held on June 23, 2022 in an online format with a headquarters in China. Currently, the leaders of the BRICS countries are Brazilian President Luiz Inácio da Silva, Russia's Vladimir V. Putin, India's Narendra Damodardas Modi, and China's Xi Jinping.

In 2017, a unique "know-how" of the Chinese chairmanship was the development of a format that was called "outreach" in the media, involving extra-regional players – the largest countries in Asia, Africa and Latin America, many of which until then were not included in the sphere of influence of the chairman country. It says a lot, the unprecedented number (twenty-eight) of countries invited to participate in the BRICS Forum of Political Parties, Brainstorm centers and Civil Organizations, which was held in Fuzhou, China, in June 2017. Among the countries that China invited to the BRICS+ dialogue were representatives of Indonesia, Malaysia, the Philippines, Cambodia, Egypt, Nigeria, Ethiopia, Kenya, Argentina, Chile, Mexico and others. Some of these countries, due to their regional influence, economic potential, size of territory and population, rightfully claim to be part of the BRICS sphere of activity for a long time.

Currently, Brazil is the 8th world economy by GDP, rich in agricultural products; Russia is the 6th world economy by GDP at PPP, has the largest reserves of mineral resources, has the largest territory in the world, one of the two largest nuclear powers in the world; India is the 3rd world economy by GDP at PPP, has cheap intellectual resources, the largest population in the world; China — 1st economy in the world by GDP at PPP and 1st exporter, named "The World Factory" in the media, holder of one of the world's largest foreign exchange reserves, one of only two countries in the world, along with India, with a population of over 1 billion; South Africa — 32nd economy in the world by GDP at PPP, has diverse natural resources.

The block's large population (about 43 % of the world's population) and significant reserves of diverse natural resources create great potential for economic growth, which some of the block's countries (China, India) have been actively realizing in recent years.

The BRICS group is attracting more and more attention and interest from various countries. On May 19, 2022, Chinese Foreign Minister Wáng Yì proposed expanding the BRICS group, which currently includes Brazil, Russia, India, China and South Africa. On June 27, 2022, Argentina and Iran applied to join the BRICS. In 2022, Turkey, Egypt, and Saudi Arabia announced their desire to become members of the BRICS. On November 7, 2022, Algeria officially applied to join the BRICS group.

Based on publicly available sources

Bionotes

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The article was submitted 24.01.2023; accepted for publication 28.02.2023.

Original article
UDC 656.073.235
doi:10.46684/2023.1.2

State and growth of container cargo flow in Russian railway transport (during COVID-19 pandemic)

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ABSTRACT The COVID-19 pandemic period in rail freight transportation in Russia is marked by indicators of rapid growth of transit traffic, export and import volumes, the average speed of transportation increase and delivery speed of transit container traffic. The positive dynamics point to the necessity of continuing research in the field of improving the quality of service in this sector of the railway industry.

Information materials of transport and logistics companies services were used. The methods and technologies used to improve the quality of service in railway transport were analyzed: reducing the delivery time of goods, increasing the average delivery speed of transit container traffic, identifying the most demanded nomenclature of goods, increasing the total volume of transit container traffic in Russia.

Currently, according to the approved Complex Plan of Modernization and Expansion of Mainline Infrastructure, by 2024 the estimated delivery time of transit container transportation across Russia in the West-East direction should be seven days, average delivery speed of transit container traffic should reach 1319 km/day, and the volume of transit container transportation should reach the level of 1656 thousand TEU (Twenty-foot equivalent unit). In this regard, it is necessary to develop a reliable methodology for determining the perspective volumes of container transportation in regular, express and high-speed trains with the identification of the most demanded nomenclature of cargo, taking into account the speed of delivery.

KEYWORDS: railway transport; JSC "Russian Railways"; COVID-19; freight traffic; transit; international transport corridors; accelerated container trains

For citation: Bushuev N.S., Shulman D.O., Rochev N.A. State and growth of container cargo flow in Russian railway transport (during COVID-19 pandemic). *BRICS transport*. 2023;2(1):2. https://doi.org/10.46684/2023.1.2.

Научная статья

Состояние и рост потока контейнерных грузов на железнодорожном транспорте России (в период пандемии COVID-19)

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АННОТАЦИЯ Период пандемии COVID-19 в области грузоперевозок железнодорожным транспортом в России отмечен показателями стремительного роста транзитных перевозок, объемов экспорта и импорта, увеличением средней скорости перевозки и скорости доставки транзитного контейнеропотока. Положительная динамика указывает на необходимость продолжения исследований в области повышения качества обслуживания в данном секторе железнодорожной отрасли.

Использовались информационные материалы сервисов транспортно-логистических компаний. Анализировались применяемые методы и технологии в области повышения качества обслуживания на железнодорожном транспорте: сокращение сроков доставки грузов, увеличение средней скорости доставки транзитного контейнеропотока, выявление наиболее востребованной номенклатуры грузов, увеличение суммарных объемов транзитных контейнерных перевозок в России.

В настоящее время согласно утвержденному Комплексному плану модернизации и расширения магистральной инфраструктуры к 2024 г. прогнозируемые сроки доставки транзитных контейнерных перевозок по России в направлении Запад – Восток должны составить семь суток, средняя скорость доставки транзитного контейнеропотока достичь 1319 км/сут, а объемы транзитных контейнерных перевозок выйти на уровень 1656 тыс. ДФЭ (двадцатифутовый эквивалент, от англ. Twenty-foot equivalent unit – TEU). В связи с этим необходима разработка надежной методики определения перспективных объемов контейнерных перевозок как в обычном, так и в скоростном и высокоскоростном движении поездов с выявлением наиболее востребованной номенклатуры грузов с учетом скорости их доставки.

КЛЮЧЕВЫЕ СЛОВА: железнодорожный транспорт; ОАО «РЖД»; COVID-19; грузопоток; транзит; международные транспортные коридоры; ускоренные контейнерные поезда

Для цитирования: *Бушуев Н.С., Шульман Д.О., Рочев Н.А.* Состояние и рост потока контейнерных грузов на железнодорожном транспорте России (в период пандемии COVID-19) // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 2. https://10.46684/2023.1.2.

INTRODUCTION

In 2021, the total volume of containers transported by Russian railroads totaled 6.5 million TEU, and for the first time in transit traffic reached the level of 1 million TEU (twenty-foot equivalent unit) [1]. It is interesting that 93 % of these transit services are accounted for by a new type of service — transportation in container trains.

As experts note, due to transportation in container trains, there is a growth in container traffic in general. According to statistics, in 2021 the number of container trains simultaneously in motion in the range of Russian railroads (*Fig. 1*) on some days exceeded 700 units and accounted for 15 % of all network trains. This is higher than in the previous two years: in 2020 — 550 trains (10 % of all network trains), in 2019 — 400 trains [1].

MATERIALS AND METHODS

The growth of container transportation is explained with the high pace of development of two major subsidiary enterprises of JSC “Russian Railways” — JSC “Russian Railways Logistics” and JSC “United Transport and Logistics Company — Eurasian Railway Alliance” (JSC “UTLC ERA”).

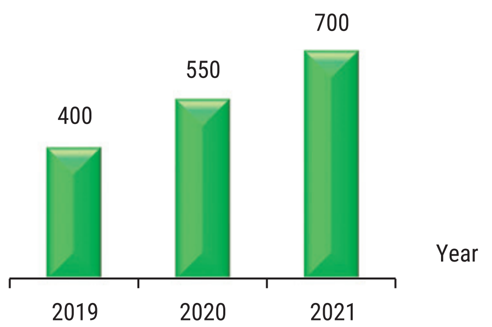

Fig. 1. The number of container trains simultaneously in motion on the Russian rail network’s polygon on a single day [1]

JSC “Russian Railways Logistics” is a huge logistics operator, which carries out transportation along the international transport corridors (ITC) East – West and North – South. In the direction of ITC East – West on the route China – Europe – China delivery time by express container trains is 14 days. All transit transportation is carried out through Russia, Mongolia and Kazakhstan. The main transit routes include the following directions: China – Europe, Korea – Europe (through China), Japan/Korea – Europe.

Since October 2016, the company is the first operator on the North-South ITC (route Mumbai (before 1995 – Bombay, India) – Moscow – Mumbai). Regarding the Caspian Sea region, the North – South ITC includes the following routes: Trans-Caspian (through the ports of Astrakhan, Olya, Makhachkala), Eastern (direct rail service through Kazakhstan, Uzbekistan and Turkmenistan) and Western (Astrakhan – Makhachkala – Samur, then through the territory of Azerbaijan to the planned border station Astara). The new 7,200 km western route from St. Petersburg to the port of Mumbai is a good alternative to the existing sea route through the Suez Canal.

In May 2019, the RZDL Trans-Siberian LandBridge service was launched for accelerated delivery of container cargo from Japan and Korea to Europe (up to 19 days) via the port of Vladivostok and the Trans-Siberian Railway.

JSC “OTLK ERA” is a joint project of Russia, Belarus and Kazakhstan to provide international rail transport. During the COVID-19 pandemic (2019–2020), the company became a leader in the Eurasian rail transit market. Over the past six-year period, there has been a steady growth in traffic volumes. In 2021, the transport network includes 84 new directions, 15 of which on the route Europe – China and 69 in the opposite direction the volume data for 2021 is almost seven times higher than in 2016 (*Fig. 2*). The specialists of

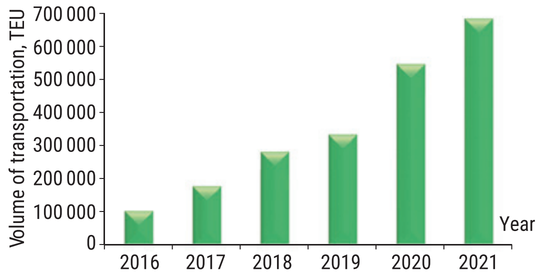

Fig. 2. JSC "OTLK ERA" transportation volumes [4]

JSC "OTLK ERA" forecast an increase in transportation speed to 1350 km/day and a reduction in transit time to 4 hours/day by 2024.

RESULTS OF RESEARCH

The results of growth in cargo transportation by railways in 2021 in comparison with the indicators of 2020 are as follows [1]:

- the share of transportation in the country increased by 6 %;
- the volume of exports — by 8 %;
- the volume of imports — by 14 %;
- the increase in transit traffic is 36 %;
- the share of loaded container shipments (of the total volume of container transportation by 2,9 %;
- the increase in the average speed of transportation was 830 km/day;
- the increase in the speed of delivery of transit container traffic — 1050 km/day (the forecast for 2024 — 1300 km/day).

In the conditions of the limited traffic-capacity of the Eastern Polygon, the use of technology for the organization of the passage of combined container trains is very relevant. According to published data, more than 4 thousand container trains will be transported in 2021 using this technology, which is 40 % more than in 2020. [1].

Experts say that one of the factors that guarantee the future growth of container transportation and optimization of time of delivery by the Russian railroads is stability of business relations between the countries of Asia – Pacific region and Europe.

Currently, JSC "Russian Railways" together with JSC "FGC" and JSC "Railway Research Institute" are developing technologies for accelerated container transportation at a speed of up to 140 km/h. The prototypes of the platform are being tested [1].

Work is constantly being done to modernize the railway infrastructure in order to increase the throughput capabilities of the container flow at the most in-demand sections and directions [2].

For the growth of transit container traffic on the East-West ITC route, most attention is paid to the development of railway checkpoints, in particular at the border crossings with China.

The holding company JSC "Russian Railways" participates in the federal project "Transport and Logistics Centers" (TLC). The aim of the project is to form multimodal freight hubs with a total capacity of at least 52.9 million tons to ensure the growth of the average commercial speed of goods movement by rail transport up to 417 km/day.

In 2022, a 2.2 km long railway bridge across the Amur River on the Russian-Chinese border section Nizhneleninskoye – Tongjiang was launched, reducing the route from Heilongjiang Province to Moscow by more than 800 km. The specific feature of the structure is a double track design for alternate passing of trains from 1520 mm rail gauge to Chinese rail gauge (1435 mm) [3].

As for the nomenclature of container cargo, for the past year 2021 positive growth dynamics was observed for all types of cargo, in particular: industrial goods — by 28 %, chemicals — 8 %, ferrous metals — 22 %, timber — 10 %, food — 19 %, higher than the previous year. Special attention is nowadays paid to the transportation of alimentary goods, such as fish products by refrigerator container (reefer).

In October 2021, the Far Eastern Railroad's loading of fish and fish products was 87.4 thousand tons, a record high for the past 10 years, and for the year — 700 thousand tons, which is 150 thousand tons more than in 2020 [1]. The positive dynamics is also noted in 2022 (*Fig. 3*). The total volume of fish products in the first half of the year amounted to 354.6 thousand tons, which is 19.6 % higher than the result for the same period of 2021 [4]. Market participants in this sector affirm that the growth of volumes is associated with the reorientation of cargo flows from road to rail transport and predict the preservation of positive dynamics.

In Russia today the largest transport and logistics center Vostok – West at the station Chernyakhovsk in Kaliningrad region is implemented. In 2019–2021 the volume of containers transit through the Kaliningrad region has increased by 7 times. The new transport and

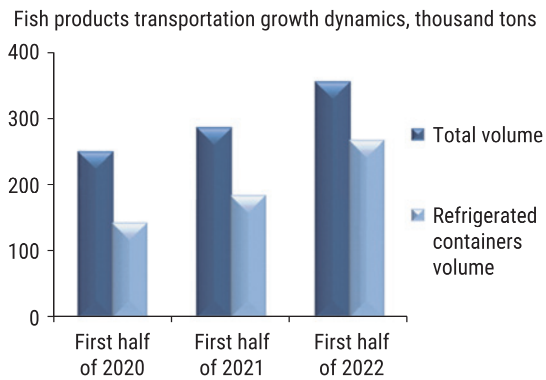

Fig. 3. Volumes of fish products transported by rail from the Far East [4]

logistics center is unique in having Russian and European railway gauge formats, is equipped to handle up to 450 thousand TEU per year and in the future can become one of the key transport and logistics hubs on the new Silk Road [5].

Express (specially organized) container trains (ECT) significantly save resources on sorting and other intermediate costs compared with single shipments [6]: the cost and delivery time is reduced. ECT can master up to 15 % of the existing volume of transit from China to Europe with the launch of new container trains in the amount of 11–16 million tons annually. The main difference between the effective operation of the ECT is regular dispatch starting from 57 conditional cars. As soon as the transit delivery time of the ECT reaches 15 days, and the train departs with a delay of one week (for example, due to weak accumulation), the use of the ECT becomes inefficient.

CONCLUSION

Represented data, as well as the research [7] show that container rail freight transport is in high demand and has a positive growth dynamics. According to the Complex plan of modernization and expansion of mainline infrastructure for the period up to 2024, by 2024 delivery time of transit container transportation in the direction West – East (Krasnoe, ports and border crossing of the North – West – Naushki, Zabaikalsk, ports and border crossing of the Far East) should reach 7 days, the average speed of transit container flow to reach 1319 km/ day, and the volume of transit container shipping to reach 1656 thousand TEU. In this regard, it is necessary to develop a reliable methodology for determining the prospective volume of container traffic in both regular and express and high-speed train traffic [8, 9].

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Contribution of the authors: the authors contributed equally to this article.
The authors declare no conflicts of interests.

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The article was submitted 14.01.2023; approved after reviewing 07.02.2023; accepted for publication 30.02.2023.

BRICS TRANSPORT
VOL. 2 ISSUE 1 2023
URBAN STUDIES, TRANSPORT AND LOGISTICS TECHNOLOGIES
УРБАНИСТИКА, ТРАНСПОРТНЫЕ И ЛОГИСТИЧЕСКИЕ ТЕХНОЛОГИИ

Original article

UDC: 625.4: 338.001.36
doi: 10.46684/2023.1.3

Feasibility study of calculation methods for tram track stiffness

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ABSTRACT Nowadays, design and construction of new urban tramlines require feasibility study of calculation methods for stiffness. A calculation method for tram track stiffness with noise and vibration insulation systems has been developed in this paper. Theoretical analysis of the impact of rail insulation systems on tram-to-slab load transfer has revealed the potential options and factors influencing the choice of a system. The new design method obtained makes it possible to predict the distribution of loads on the load-bearing foundation surface. Different variants of rail/slab load distribution have been determined depending on the mechanical characteristics of rail profiles. Tram track slab stiffness has been calculated for three design models such as rigid surface pavement, bridge structure and foundation slab. The design of the tram track as foundation slab allows calculating slab reinforcement as accurately as possible because the surface pavement takes into account the planned service life and tram flow density in the area under survey.

Field experiments have demonstrated a better convergence of theoretical and experimental data when designing the slab as foundation. As a result, a new method for calculating the foundation slab stiffness of a tram track has been proposed taking into account planned service life, tram flow density and other factors.

KEYWORDS: tram track; non-ballasted structure; design model; calculation method; track rail profiles; cyclic tests

For citation: Dudkin E.P., Mohsin A.H.A., Sultanov N.N. Selection and analysis of calculation methods for tram track strength. *BRICS transport*. 2022;2(1):3. https://doi.org/10.46684/2023.1.3.

Научная статья

Выбор и обоснование методики расчета трамвайного пути на прочность

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АННОТАЦИЯ Строительство современных трамвайных линий и создание новых конструкций требуют обоснования методов расчета на прочность. Приведена методика расчета конструкции трамвайного пути на прочность при условии применения в ней систем шумо- и виброизоляции. Теоретический анализ влияния систем изоляции рельса на схему передачи нагрузки от трамвая на плиту показал возможные варианты и позволил выявить факторы, от которых эта схема зависит. Полученная новая расчетная схема дает возможность спрогнозировать распределение нагрузок на поверхность несущего основания. В зависимости от механических характеристик вкладышей определены варианты распределения нагрузки от рельса на плиту. Расчет плиты на прочность выполнен по трем схемам, как: дорожной одежды жесткого типа, мостовой конструкции и фундаментной плиты. Расчет трамвайной конструкции как фундаментной плиты дает возможность максимально точно учесть конструктив плиты (армирование), а расчет как дорожной одежды — учесть планируемый срок эксплуатации и интенсивность движения трамваев по исследуемому участку.

Полевые испытания продемонстрировали лучшую сходимость теоретических и опытных данных при расчете плиты как фундаментной. Благодаря анализу методов расчета предложили новую методику расчета несущей плиты трамвайного пути на прочность, которая учитывает планируемый срок эксплуатации, интенсивность движения трамваев и ряд других факторов.

КЛЮЧЕВЫЕ СЛОВА: трамвайный путь; безбалластная конструкция; расчетная схема; методика расчета; прирельсовые профили; циклические испытания

Для цитирования: *Дудкин Е.П., Мохсин А.Х.А., Султанов Н.Н.* Выбор и обоснование методики расчета трамвайного пути на прочность // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 3. https://doi.org/10.46684/2023.1.3.

INTRODUCTION

The calculation of tram track stiffness is based on the calculation of stiffness in its foundation components. There are two types of tram track design such as rail-sleeper structure and monolithic (concrete slab) structure. Design of tram tracks on sleepers is a standard procedure today as conventional methods are used for calculating a railway track [1]. The design of a monolithic slab as load-bearing foundation requires feasibility study of calculation methods as it is necessary to take into account the specific features of this type of design.

RAIL DYNAMICS CONSIDERATIONS IN RELATION WITH RAIL AND SLAB INSULATION SYSTEMS

The tram track slab is laid on a prepared sub-slab base layer consisting of sand, crushed stone and concrete. Depending on the conditions, the thickness of the structural layers varies and therefore the modulus of elasticity of the base layer on which the track slab is placed varies too. Another feature of modern tram track structures is the use of insulating materials such as rail profiles and/or vibration insulating mats (*Fig. 1*) [2–6].

According to the standard calculations of tram track stiffness, it is necessary to calculate the distribution of load from the tram to the load-bearing concrete slab. Theoretically, three options can be considered: point load from each wheel, load distributed over the section between the wheelset axles, and point load under the rail at the wheelset centre as it is the point of rail maximum deflection. Therefore, studies on the dependence of rail deflection on the coefficient of the plantar profile bedding and the tram axial load are important as they determine the rail/slab load transfer [7–15]. Rail deflection was calculated using formula (1).

$$y(x_n) = \sum_{j=1}^{N} \frac{P_j}{\beta^3 EI_z} e^{(-\beta|x_n - x_j|)} \times \times \left(\cos\left(-\beta|x_n - x_j|\right) + \sin\left(-\beta|x_n - x_j|\right)\right), \quad (1)$$

where x_n is the load application coordinate; N is the number of sections the rail is divided into; P_j is the tram axial load, kN; β is the slab relative stiffness modulus; x_j is the coordinate of the section under consideration; EI_z is the rail bending elasticity, Hm².

Calculations on rail deflection under different axial loads with different coefficients of the plantar profile bedding are shown in *Fig. 2 and 3*.

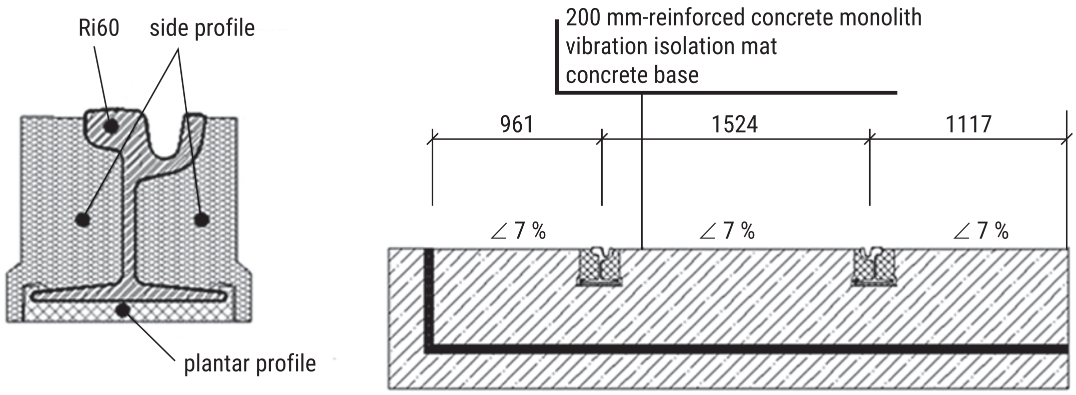

Fig. 1. Application of insulating materials

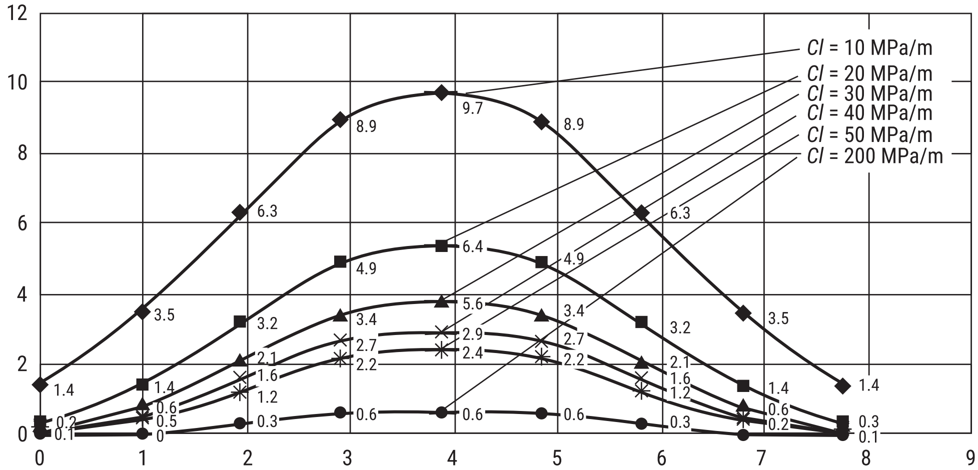

Fig. 2. Rail deflection (mm) depending on the coefficient of the plantar profile bedding C_1 (MPa/m) at P_{os} = 83.3 kN/axis in different sections

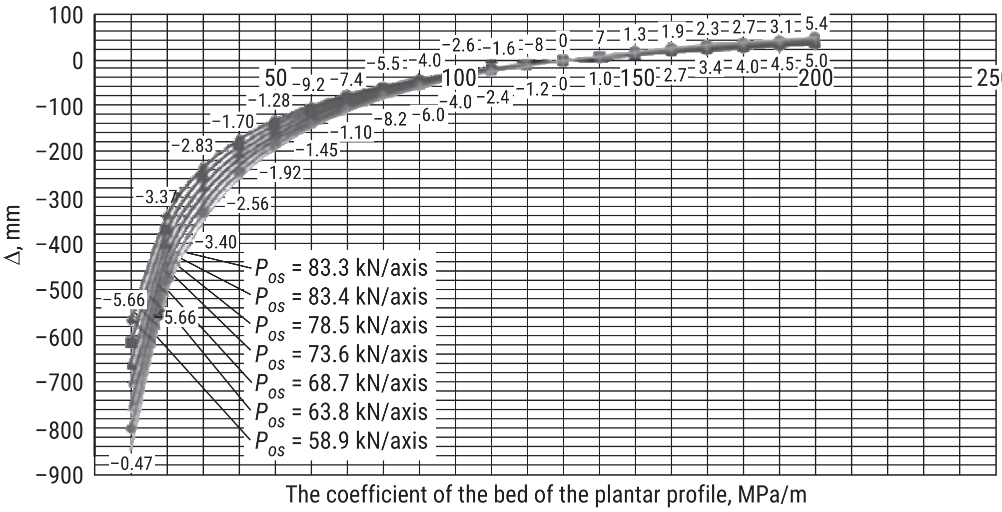

Fig. 3. Rail deflection $\Delta = \Delta_{abs} = h_k - h_s$ (mm · 10^{-3}) under different axial loads Pos (kN/axis) depending on the coefficient of the plantar profile bedding C_1 (MPa/m), where h_k is rail deflection under tram car wheels; h_s is rail deflection at the midpoint between wheel pairs

The studies have shown that the axial load does not effect the rail deflection shape. This depends mainly on the coefficient of the plantar profile bedding. Theoretically, we can assume three types of load transfer from the tram bogie through the rail to the concrete slab surface depending on the stiffness of the plantar profile (*Fig. 4–6*). They are point load (separately from each wheel), load distributed in the section between the wheelset axles, and point load from the rail in the centre between the wheels, given rail maximum deflection in that section (*Fig. 2*) [7–11].

A tram track on a monolithic foundation can be calculated according to three types of design such as rigid surface pavement, bridge structure and foundation slab [3, 6, 7]. According to these three types, the calculations were made taking into account the specifics of rail/slab load transfer.

The analysis of the results showed that the calculation of the tram track-bearing slab as a rigid surface pavement is limited to the determination of stiffness factor K_{pr}. It is calculated by the formula

$$K_{pr} = 1{,}0 < \frac{R_{ri}^{rasch}}{\sigma_{pt}}, \tag{2}$$

where R_{pt}^{rasch} is calculated concrete tension stiffness at bending, σ_{pt} is tensile stresses at bending caused by load action on the concrete slab taking into account the temperature difference across the thickness of the slab.

This method of calculation does not allow determining the distribution of forces arising in the slab in sections and does not take into account the nature of reinforcement. As a result, we obtain stresses only at the points of rail/concrete surface contact.

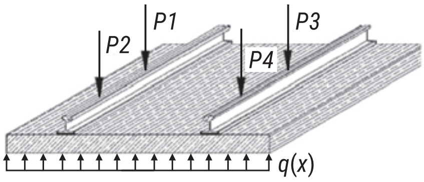

Fig. 4. Load transfer to the bearing concrete slab with plantar profile stiffness over 130 MPa/m

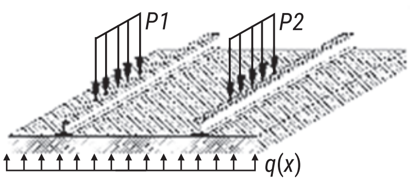

Fig. 5. Load transfer to the load-bearing concrete slab with the planar profile stiffness of 130 MPa/m

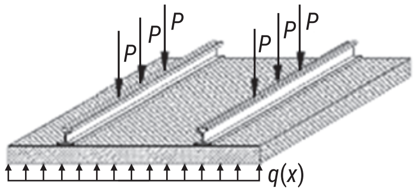

Fig. 6. Load transfer to the bearing concrete slab with the planar profile stiffness from 10 to 130 MPa/m

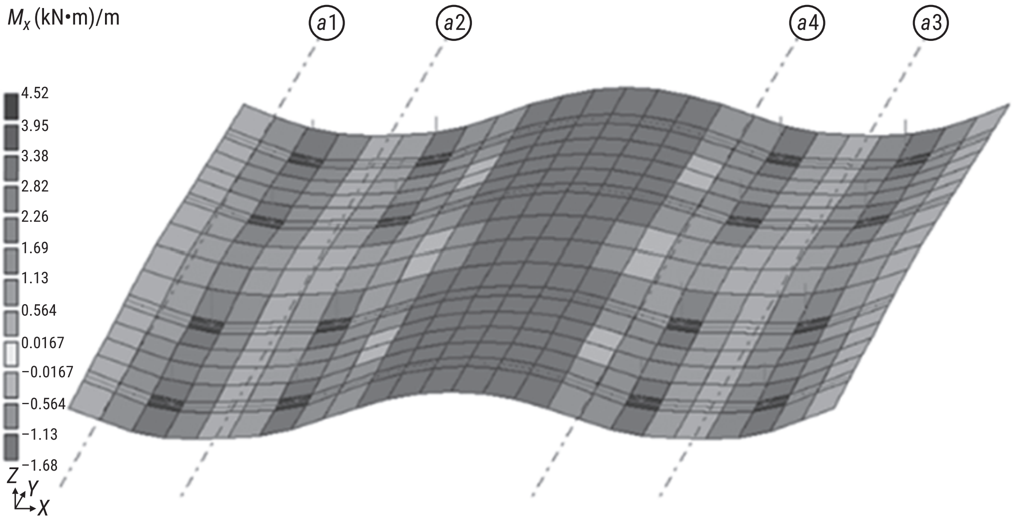

Fig. 7. Mosaic of stresses due to bending moment M_x (kN/m) with axial load of 58.86 kN/axis and coefficient of planar profile bedding C_1 = 50,000 kN/m

The design of the tram track stiffness as a bridge structure using a simplified calculation scheme (beam on two supports) is unacceptable. The calculations are reduced to the slab with elastic foundation that is the foundation slab without taking into account the base layer performance under the slab [12–19].

When the tram track is designed as foundation slab, the forces occurring in each final element are determined (*Fig. 7*), thus, allowing us to analyse the overall stress state of the slab with different variants of its reinforcement.

To verify the results of theoretical calculations, laboratory and field tests were carried out. For laboratory tests, a tram track structural element was made and it was subjected to cyclic loads. Thus, the dependence of the stresses caused in the track structural elements on its service life was obtained [11, 15, 19]. The test bench is shown in *Fig. 8*.

The results are presented in *the Table*.

The analysis of the results obtained confirms that the qualitative picture of the stress distribution in the slab obtained in the theoretical and laboratory studies is similar. As the number of cycles increased, the stiffness characteristics of the rail profiles were modified, which should be taken into account when developing the design model.

Field tests were carried out using strain gauges to measure the stresses in the concrete slab as the tram passed (*Fig. 9*).

The experimental studies have shown that the calculation data of the tram track as a foundation slab have the greatest convergence with the experimental data (the difference between the experimental and theoretical results was 16 %) [2, 5].

This method can be recommended for designing a tram track on a concrete slab. It provides for the cal-

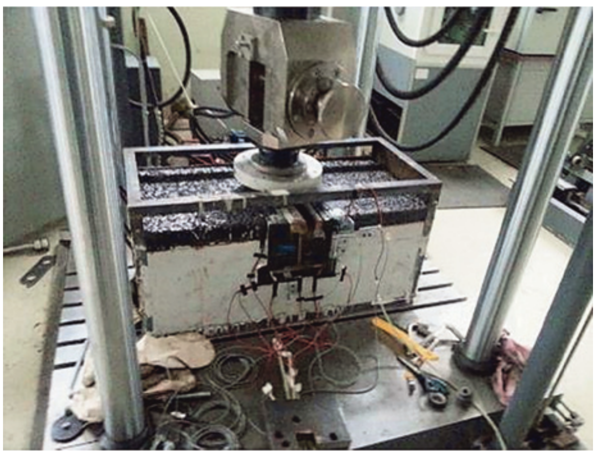

Fig. 8. A tram track structural element used in cyclic tests

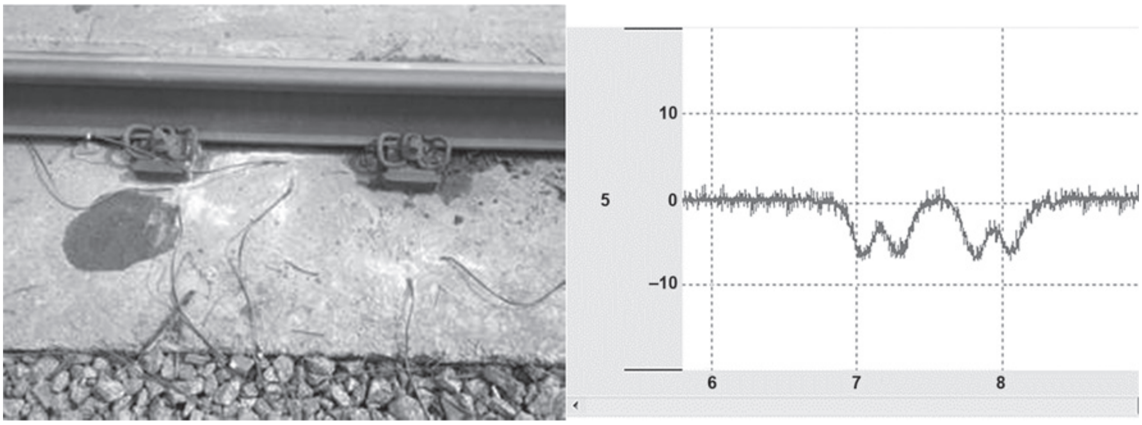

Fig. 9. Example of recording the bending stresses σ_x (kg/cm^2) in the slab during the passage of an empty tramcar

Table

Cycles completed, million	Stresses, kgf/cm^2							
	Concrete under rail foot (compression in all areas)							Rubber "at the lip", horizontal (tension)
	Below "left" edge, horizontal	Below "left" edge, vertical	In the rail axis, horizontal	In the rail axis, vertical	Below "right" edge, horizontal	Below "right" edge, vertical	Safety margin, %	
0	−(7–8)	−(13–15)	−(31–33)	−(7–8)	−(8–10)	−(7–8)	87	+(1–1,2)
3,37	−(8–10)	−(10–15)	−(34–38)	−(7,5–9,5)	−(9–12)	−(7,5–9)	86	+(0,7–0,9)
6,755	−(7,5–9)	−(9–12)	−(33–39)	−(7–8)	−(7–10)	−(7–9,5)	85	+(0,7–0,9)
9,94	−(8–9)	−(12–14)	−(34–39)	−(9–10,5)	−(9–11,5)	−(11–12)	85	+(0,7–0,9)

culation of the tram track structure in two stages: the determination of the sub-slab layer bedding coefficient and the determination of the bending forces generated in the load-bearing slab. At the same time, the design of the tram track as rigid surface pavement makes it possible to take into account a number of factors that influence the stiffness of the structure, such as traffic density, duration of load application, etc., by introducing relevant factors which are not taken into account in the design as foundation slab. It is therefore necessary to synthesize these two calculation schemes. As a result, a formula is proposed for calculating the stiffness of the tram track load-bearing slab that takes into account all the factors mentioned above.

$$R_{bt,f} = \sigma_{ri,f} \cdot k_y \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4,$$

where $R_{bt,f}$ is the design tensile stiffness of concrete at bending; $\sigma_{ri,f}$ is the standard tensile stiffness of polymer-fibrated concrete at bending; k_y is the fatigue factor of concrete under repeated loads. It is determined by the formula

$$K_y = 1{,}08(\Sigma N_p)^{-0{,}063},$$

where ΣN_p is the total number of applications of the given load during the calculated lifetime; k_1 is the coefficient of concrete behaviour which takes into account duration of the load action; k_2 is the coefficient of concrete behaviour which takes into account the concrete layer height; k_3 is the coefficient of concrete behaviour which takes into account the alternate freezing and thawing of concrete; and k_4 is the coefficient of concrete behaviour which takes into account the character of concrete structure failure.

CONCLUSION

The calculation of the stiffness of a tram track load-bearing slab as foundation shows the most reliable results as the difference between theoretical and experimental data is 16 %. This method makes it possible to determine the stresses caused in each element taking into account the nature of reinforcement. This allows analyzing the overall stress state of the slab. The improved method mentioned above (taking into account additional factors) is recommended for calculation of the tram track load-bearing slab for stiffness.

The linear dependence of occurring bending stresses on the sub-slab layer stiffness and axial loads within given tram axial loads and bedding coefficient allows for the unification of consolidated tables of values occurring in the tram track load-bearing slab depending on the bedding coefficient and tram axial load for a given slab geometry. Thereby simplifying the calculations for the slab stiffness.

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Contribution of the authors: the authors contributed equally to this article.
The authors declare no conflicts of interests.

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The article was submitted 14.07.2022; approved after reviewing 18.10.2022; accepted for publication 30.02.2023.

Original article
UDC 625.033.34
doi: 10.46684/2023.1.4

Modulus of elasticity of non-ballasted track

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ABSTRACT The main stiffness properties that determine the stresses in the track structure components under loads from a moving train are the modulus of elasticity of the rail slab and the slab-track/rail correlation stiffness coefficient. These parameters have been investigated for a ballasted track and are well established today, in contrast to those of a non-ballasted track. This study aims at determining the stiffness characteristics of a non-ballasted track, comparing them with those of a ballasted track, and assessing their effect on the stress-strain state (SSS) of the elements of a non-ballasted track structure. Field experiments to measure the stresses in the track structure elements were carried out using strain-gauge methods. As a result of the experiments, the modulus of elasticity and the correlation stiffness coefficient of the rail slab and the rail were determined for the RHEDA2000 slab track system. The results obtained prove it possible to apply a rail-as-beam-on-elastic-foundation theory and to use well-established calculation methods for designing a non-ballasted track structure suitable for different operational conditions.

KEYWORDS: non-ballasted (ballastless) track; modulus of elasticity of rail slab; rail slab/rail correlation stiffness coefficient; RHEDA 2000 non-ballasted track design; model of beam on a continuous elastic foundation; strain-gauge method

For citation: Ivanova K.I., Kolos A.F., Wang X. Modulus of elasticity of non-ballasted track. *BRICS transport*. 2022;2(1):4. https://doi.org/10.46684/2023.1.4.

Научная статья

Упругие характеристики подрельсового основания безбалластного железнодорожного пути

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АННОТАЦИЯ Основными упругими характеристиками, определяющими значения напряжений в элементах конструкции верхнего строения пути под нагрузкой от движущегося поезда, являются модуль упругости подрельсового основания и коэффициент соотносительной жесткости подрельсового основания и рельса. Значения этих параметров для пути с ездой на балласте сегодня исследованы и хорошо известны, в отличие от безбалластного пути. Цель исследования — натурное определение упругих характеристик безбалластного железнодорожного пути, их сравнение с аналогичными характеристиками для пути на балласте и оценка воздействия данных характеристик на напряженно-деформированное состояние элементов верхнего строения безбалластного пути. Натурные испытания по измерению напряжений в элементах верхнего строения пути осуществлялись с помощью тензометрических методов. В результате экспериментов установлены значения модуля упругости подрельсового основания и коэффициента соотносительной жесткости подрельсового основания и рельса для безбалластной конструкции RHEDA2000. Полученные результаты дают возможность рассматривать рельс как балку, лежащую на сплошном упругом основании, применительно к безбалластному пути и использовать известные методы расчета для проектирования железнодорожного пути с устройством безбалластной конструкции в зависимости от условий эксплуатации.

КЛЮЧЕВЫЕ СЛОВА: безбалластный путь; модуль упругости подрельсового основания; коэффициент соотносительной жесткости подрельсового основания и рельса; конструкция безбалластного пути RHEDA 2000; модель балки, лежащей на сплошном упругом основании; тензометрический метод

Для цитирования: *Иванова К.И., Колос А.Ф., Ван С.* Упругие характеристики подрельсового основания безбалластного железнодорожного пути // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 4. https://doi.org/10.46684/2023.1.4.

INTRODUCTION

At present, the railway transport in the Russian Federation has been developing due to the continuous expansion of the fast and high-speed railway networks and an increase in railway carrying capacity together with the growing volume of freight and passenger traffic. On sections with speeds above 160 km/h (on fast and high-speed sections), there is a worldwide practice of switching to slab track systems as the most low-maintenance and long-lasting (up to 50–60 years) structures [1]. Non-ballasted track systems require significant capital investment but they have a number of advantages over ballasted track structures. These advantages lie in the reduction of maintenance costs, improved train ride quality and passenger ride comfort as well as reduced fuel and energy consumption required for train traction and others [2].

World practices in the operation of non-ballasted track systems have shown their cost effectiveness under certain operational conditions [3]. There are more than 30 types of non-ballasted track systems in the world today, but choosing a certain system for specific operational conditions remains a complicated task [4]. One of the reasons is a lack of easy methods for calculating the stress-strain state (SSS) of a ballastless track, which would take into account the specifics of the designed structure, engineering and geological conditions of construction, operational conditions in the future, etc. The calculation methods known today are labour-intensive and require a considerable amount of input data. In addition, their application will be challenging for ordinary engineering personnel in design organisations due to their mathematical complexity. When comparing rail performance in ballasted and non-ballasted track structures, the rail can be modelled as a beam resting on a continuous elastic foundation [5]. Due to this method, it is possible to carry out the assessment of the track structure SSS using well-established theories and calculation methods.

The evaluation of the track elements SSS for a conventional ballasted track is carried out in accordance with the track stiffness calculation methods based on the above-stated assumption that a rail is a beam on an elastic foundation [6]. In accordance with these methods, the Schwedler-Zhuravsky theorem for the curved rail axis is applied

$$EI\frac{d^2y}{dx^2} = M \text{ или } -EI\frac{d^4y}{dx^4} = \frac{d^2M}{dx^2} = q, \qquad (1)$$

where E is the modulus of elasticity of rail steel; I is the inertia moment of the rail cross-section in relation to its central horizontal axis passing through the centre of gravity of a section; y is the rail transverse elasticity under load; M is the bending moment; q is the rail slab performance.

In equation (1), a linear dependence between the rail transverse elasticity and the rail slab performance is defined and is expressed by the modulus of elasticity of the rail slab U

$$q = -U \cdot y. \qquad (2)$$

Integration of equation (1) with dependence (2) makes it possible to determine the rail transverse elasticity, the bending moment value and the rail pressure on the sleeper (formulae (3)) [7].

$$y = \frac{Pk}{2U}e^{-kx}(\cos kx + \sin kx),$$

$$M = \frac{P}{4k}e^{-kx}(\cos kx - \sin kx), \qquad (3)$$

$$Q = Uyl = \frac{Pkl}{2}e^{-kx}(\cos kx + \sin kx),$$

where l is the distance between sleeper axes; k is the correlation stiffness coefficient of the rail slab and the rail determined by the relation

$$k = \sqrt[4]{\frac{U}{4EI}}. \qquad (4)$$

According to formula (3), the bending moment is proportional to the ordinates of the influence line μ_{kx} that are defined by the relation (formula (5)). Graphically, μ_{kx} function is shown in *Fig. 1*. Fig. 1 also shows the position of the dynamic vertical forces acting from the rolling stock wheels on the rails.

$$\mu_{kx} = e^{-kx}(\cos kx - \sin kx). \qquad (5)$$

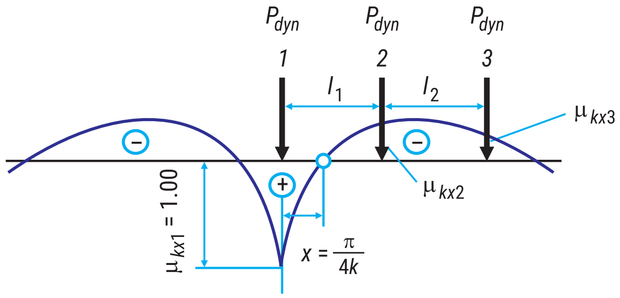

Fig. 1. Diagram showing the bending moment of a rail modelled as beam on a continuous elastic foundation

Fig. 1 shows that the bending moment line crosses the horizontal axis at points that have equal ordinates: $x = \pi/4k$, then, $x = 5\pi/4k$, etc. Thus, knowing the distances x it is possible to find experimentally the correlation stiffness coefficient of the rail slab and rail k, and further, using formula (4) and expressing U through k, to find the modulus of elasticity of the rail slab.

$$U = 4 \cdot E \cdot I \cdot k^4. \quad (6)$$

U and k are design characteristics of a railway track and have been well researched for a ballasted track structure [8]. The mean U-value for a ballasted track with reinforced concrete sleepers varies between 50–120 MPa; and for a track with timber sleepers, it is 20–30 MPa. The change in the values depends on the elastic properties of the rail pads, the sleeper layout, the elastic properties of the ballast bed and the subgrade or formation. The stiffness coefficient of the rail foundation and the rail is also determined by the elastic properties of the rail steel and the actual rail cross-section geometry (from 1.10 m^{-1} to 1.6 m^{-1} is for a track with reinforced concrete sleepers; and from 0.90 m^{-1} to 1.1 m^{-1} is for a track with wooden sleepers).

The stiffness properties of a non-ballasted track have not been thoroughly investigated, which makes it difficult to use the beam model on elastic foundation for the calculation of the track components' SSS. In this regard, it is an urgent engineering task to experimentally determine the stiffness properties of a non-ballasted railway track.

RESEARCH METHODS

Field experiments to determine the modulus of elasticity and correlation stiffness coefficient of rail slab and rails on RHEDA 2000 non-ballasted track were performed on the Sablino – Tosno 46-km section of St. Petersburg – Moscow line (II main track, 45 + 65,00 kilometer post). Non-ballasted track features are shown in *Fig. 2*.

The experiment took place on a track section laid on an embankment of medium-grain sand, with light powdery loam ranging from solid to semi-solid at the base of the embankment. The track consisted of continuous welded P65 rails, VOSSLOH fastenings and German-made sleepers with a layout of 1840 pcs/km. Sleepers were embedded in a load-bearing reinforced B40-class concrete slab of 240 mm thickness. It is laid on a 300-mm-thick foundation slab of B15 concrete. A 40cm-thick protective layer of sand-and-gravel mix is installed under the track foundation slab (*Fig. 2*).

Empty freight trains with the VL10 locomotive, long-distance passenger trains with the EP2K locomotive, ER suburban electric trains, and regional Lastochka ES1high-speed electric trains were running on the section during the experiment. The freight trains' speeds varied between 40–80 km/h, and passenger trains' speeds were between 40–110 km/h.

In order to identify the distance x = p/4k (*Fig. 1*), resistance strain gauges were attached to the bottom edge of the outer rail. The resistance strain gauges conformed to the requirements of GOST 21616 91 "Resistance Strain gauges. General technical requirements". They were attached to the rail bottom with special glue

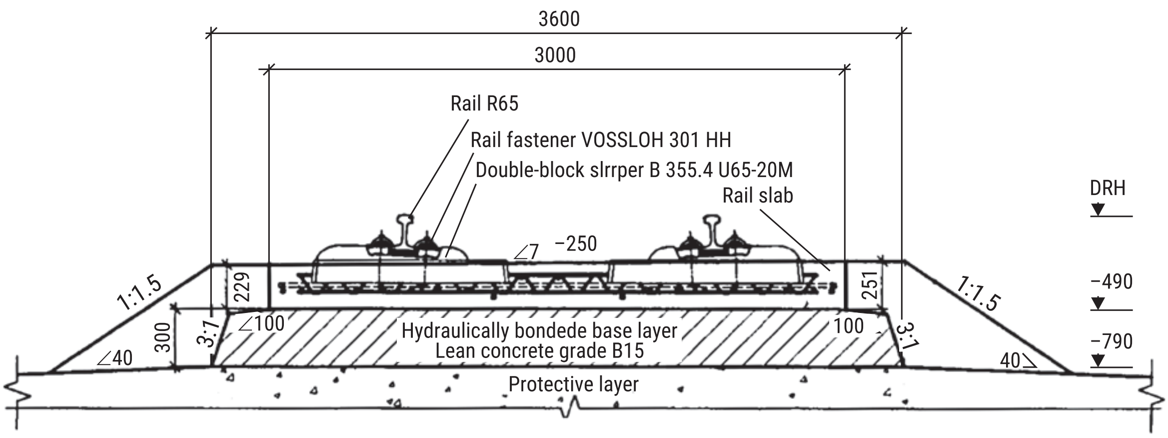

Fig. 2. Design of RHEDA 2000 non-ballasted track system

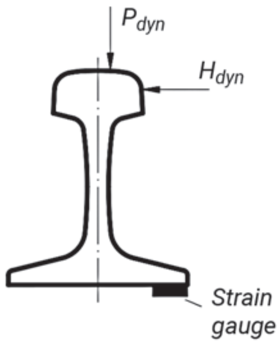

Fig. 3. Strain gauge glued to the rail bottom

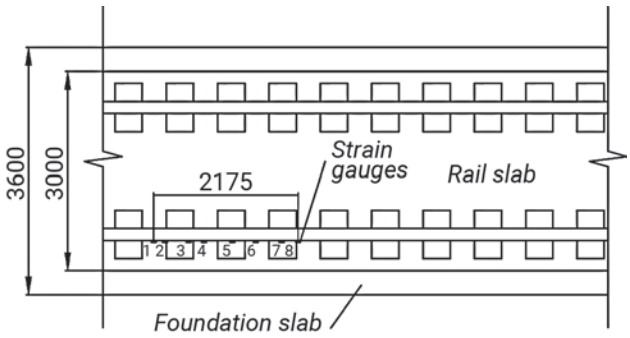

Fig. 4. Lengthwise layout of strain gauges attached to the rail bottom

at a distance of 3 mm from the outer edge of the rail, as shown in *Fig. 3* [9].

The strain gauges were installed every 10–50 cm lengthwise. There were 8 measuring points on a 2.175 m-long rail. The layout of the strain gauges in the experimental section is shown in *Fig. 4*.

The strain gauges were electrically connected in a bridge circuit. An active strain gauge with ohmic resistance R_1 was included in an unbalanced bridge shown in *Fig. 5*.

The measuring circuit was calibrated using a cantilevered beam of equal resistance (*Fig. 6*), onto which strain gauges from the same batch as those used in the experiment were attached with glue [10].

The procedure for calibrating the gauge circuit was as follows: strain gauge R_1 was glued to the bottom edge of the rail, a bridge circuit was assembled, then calibration strain gauge R_2 was connected to one arm, and finally, strain gauges with constant electrical resistance R_3 and R_4 were connected to the other two arms. With the adjustment of R_2 gauge resistance, the bridge circuit was brought to a balanced position, i.e. the value of the current across the diagonal of the bridge was zero. Then a load of certain mass was suspended from the beam with equal resistance thus generating P_i force (*Fig. 6*) and, correspondingly, causing M_i bending moment. The use of a beam with equal resistance showed that the bending stresses $\sigma_{T\text{-}i}$ at any cross-section point are the same when P_i force is applied. Therefore, the bending stresses can be determined by the formula

$$\sigma_{T-i} = \frac{M_i}{W},, \tag{7}$$

where M_i is the bending moment, W is the moment of resistance of the beam with equal resistance.

According to formula (8), the bending moment will be

$$M_i = P_i \cdot l. \tag{8}$$

With the force P_i acting on the beam, the bridge circuit was unbalanced and the current value I_T was detected in the arm of the bridge. Knowing the absolute value of bending stresses in the beam and registering current $I_{T\text{-}i}$, gauge factor $K_{T\text{-}i}$ was determined.

$$K_{T-i} = \frac{\sigma_{T-i}}{I_{T-i}}. \tag{9}$$

Thus, a further research was aimed at determining the bending stresses in the rail σ_p by using a gauge factor to convert the current value in the unbalanced

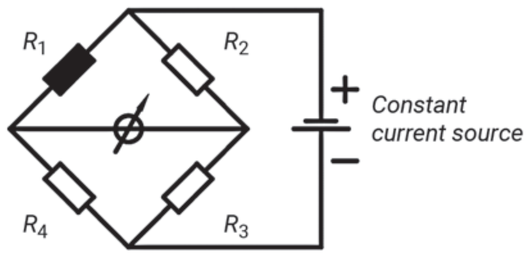

Fig. 5. Bridge connection circuit of strain gauges: R_1 is an active sensor attached to the bottom edge of the rail; R_2 is a calibrating sensor; R_3 and R_4 are resistors with constant electrical resistance

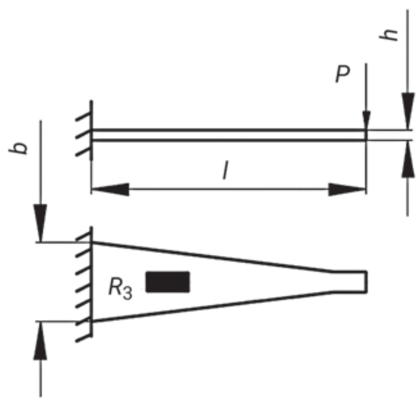

Fig. 6. Cantilever beam of equal resistance for calibrating the measuring circuit: *h* is beam thickness equal to 0.5 cm; *l* is beam length equal to 20 cm; *b* is beam width equal to 8 cm; *P* is force application point

bridge diagonal Ichan when the wheel-to-rail load was applied

$$\sigma_r = K_\text{т} \cdot I_{chan}. \quad (10)$$

During the experiment, the readings of all strain gauges were recorded simultaneously. It allowed processing the results and determining the bending stresses in the rail bottom edges at the same time at different positions of the rolling stock axles relative to the attached strain gauges.

The experimental measurements were processed using conventional methods of mathematical statistics. Statistical series were formed so that one statistical series comprised the values of measured stresses corresponding to one type of rolling stock, fixed axle load and certain train speeds. The probability level in processing the results was assumed 0.994. The main interest was in the mean values of the rail bottom edge stresses, their maximum possible values and the coefficients of variation.

RESEARCH RESULTS

According to the well-known formulae [11], the rail bottom edge stresses can be determined according to the following dependence

$$\sigma_{r-s} = \frac{M_r}{W_r} f, \quad (11)$$

where M_r is the bending moment in the rail caused by the passage of the rolling stock, W_r is the resistance moment in the rail in relation to the furthest fiber at the bottom, f is the transition factor from axial stresses to edge stresses. The value of the latter can be accepted in accordance with the Methodology for assessing the impact of rolling stock on the track to ensure its reliability (RF Railway Ministry, CPT-52/14).

Applying formula (3) in expression (11) including expression (5), we obtain

$$\sigma_{r-s} = \frac{P \cdot f}{4 \cdot k \cdot W_r} \cdot \mu_{kx}. \quad (12)$$

Expression (12) shows that the edge stresses at the rail bottom and the ordinates' influence line of the bending moment will be in direct proportion. Consequently, the edge stresses curve in the rail along its length will coincide with the bending moment curve, while zero edge stresses will be at the point at a distance of $x = \pi/4k$ from the first axis of the train bogie [12]. Recording the movement of the front train bogie axis over the first strain gauge (*Fig. 4*), with the train running from left to right (*Fig. 4*), it is possible to construct the stresses curve in the rail edge acting at the same moment, thereby determining the distance x corresponding to the horizontal coordinate $\pi/4k$ by interpolation (*Fig. 4*). Due to the obtained value of $x = \pi/4k$, the rail slab/rail correlation stiffness coefficient is determined in reverse movement. Modulus of elasticity of the rail slab is calculated using formula (6).

Using this approach and experimental measurements, mean values of the modulus of elasticity of track slab U for different types of rolling stock running at different speeds were calculated. The results are shown in the table below.

DATA ANALYSIS

Based on the data obtained, *Fig. 7* shows the dependencies of the modulus of elasticity of the rail slab on the type of rolling stock and speed changes.

Table

Modulus of elasticity of RHEDA 2000 non-ballasted track

Type of train	Modulus of elasticity of the RHEDA 2000 U non-ballasted track, MPa, at train speeds, km/h						
	от 40 (incl.) до 50 (excl.)	от 50 (incl.) до 60 (excl.)	от 60 (incl.) до 70 (excl.)	от 70 (incl.) до 80 (excl.)	от 80 (incl.) до 90 (excl.)	от 90 (incl.) до 100 (excl.)	от 100 (incl.) до 110 (excl.)
ER electric train	60,0	60,0	59,8	60,0	59,9	59,8	59,5
Lastochka ES electric train	–	–	59,0	58,7	58,9	58,9	58,9
EP2K Locomotive	61,0	60,9	60,8	60,8	60,8	60,7	60,6
VL10 Locomotive	61,0	61,0	61,0	61,0	–	–	–
Passenger car	59,9	59,9	59,8	59,8	59,8	59,8	59,7
Mean	**60,7**	**60,6**	**60,5**	**60,5**	**60,3**	**60,3**	**60,2**
Mean				**60,4**			

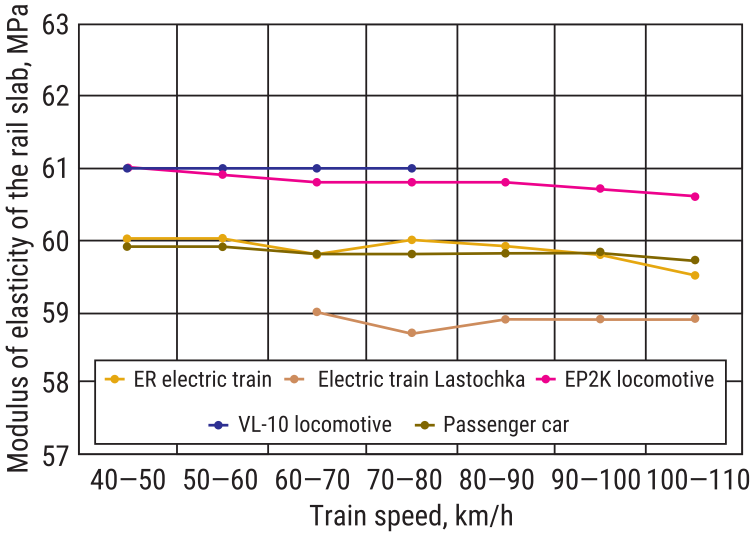

Fig. 7. The effect type of rolling stock and movement speed on the modulus of elasticity of RHEDA 2000 non-ballasted track

The analysis of the experimental data and statistical process results show that the modulus of elasticity of the rail slab varies from 58.9 to 61.0 MPa for all types of rolling stock at different speeds. The discrepancy of the results does not exceed 3–5 % as a rule. For further engineering applications, the modulus of elasticity of RHEDA 2000 non-ballasted track structure can be accepted to be 60 MPa.

A number of scientific papers [13] state that one of the main disadvantages of ballastless track design is considered to be its high stiffness. Track stiffness RT is known to be numerically equal to the force applied to the rail causing its elastic deflection equal to 1, i.e. track stiffness is directly related to the rail slab modulus of elasticity [14].

$$R_T = \frac{2U}{k}. \quad (13)$$

The experimental results demonstrate that RHEDA 2000 non-ballasted track does not show any significant increase in stiffness compared to a ballasted railway track with reinforced concrete sleepers. The mean value of the modulus of elasticity of the rail foundation for a typical ballasted track is 50–120 MPa [15], whereas for the non-ballasted RHEDA 2000 track it is only 60 MPa. Since the stiffness of the entire track is determined by the stiffness of track elements, the results obtained can be attributed to the use of VOSSLOH W-301-HH fasteners with high elasticity rail pads.

CONCLUSION

The experimental data on determining the modulus of elasticity and rail slab/rail stiffness coefficient of RHEDA 2000 non-ballasted track structure provide a number of key conclusions:

- modulus of elasticity and slab/rail correlation stiffness coefficient for RHEDA 2000 non-ballasted track with train speeds between 40 and 110 km/h do not depend significantly on the type of rolling stock. The variances do not exceed 3–5 %;
- the mean modulus of elasticity of rail slab for RHEDA 2000 non-ballasted track was 60 MPa, which indicates no increase in the stiffness of the ballastless track compared to the ballasted track. The results can be attributed to the use of VOSSLOH W-301-HH fasteners with high elasticity rail pads;
- the obtained elastic properties for RHEDA 2000 rail slab track make it possible to use the model of beam resting on a continuous elastic foundation to determine the strain-stress state of all non-ballasted track components.

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Contribution of the authors: the authors contributed equally to this article.
The authors declare no conflicts of interests.

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The article was submitted 14.07.2022; approved after reviewing 18.08.2022; accepted for publication 30.02.2023.

Original article
UDC 69.003:65
doi: 10.46684/2023.1.5

Management and engineering solutions for railway station development

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ABSTRACT This paper presents a methodology for construction engineering management of railway station redevelopment. The station working capacity is taken into account and the stages of preliminary and main works are determined. The scope of work to be performed by a building contractor is substantiated to provide an optimal station performance. The volume and scopes of work for specific and complex construction workflows are grouped by the components of the railway marshalling yard.

The optimal volume of work of the complex flow *F* has been determined (as a percentage of the total estimated cost of the facility). The station working capacity *Nв* has been taken into consideration in correlation with the given conditions of construction or renovation works.

The key construction flow management options have been worked out based on the optimal index of construction work sequence, prime cost reduction of construction and installation works (current costs *C*), and effective capital investments into machines and mechanisms (one-time costs K_f).

The proposed methodology for construction management and engineering solutions is oriented to general contracting and subcontracting companies of the railway construction sector. This methodology is intended to lower the prime cost of construction and installation works and to reduce the time of construction and redevelopment of railway stations.

KEYWORDS: railway stations; coefficient of construction sequence; volume of work; construction flow system; station working capacity; generation of work scopes; rational coefficient of construction sequence; optimization methodology; optimization of management and engineering solutions; technological layout; coefficient of construction flow sequence

For citation: Kabanov A.V., Marshavina O.A. Management and engineering solutions for railway station development. *BRICS transport*. 2023;2(1):5. https://doi.org/10.46684/2023.1.5.

Научная статья

Разработка организационно-технологических решений по переустройству железнодорожных станций

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АННОТАЦИЯ Разработана методика организационно-технологического проектирования переустройства железнодорожных станций. Учитывается перерабатывающая способность станции и определяется порядок этапности осуществления подготовительных и основных работ. Обосновывается размер фронта работ подрядной строительной организации, позволяющий обеспечить оптимальную производительность станции. Объемы и фронты работ для специализированных и комплексного потоков группируются по элементам железнодорожной сортировочной станции.

Определена оптимальная величина (в процентах от общей сметной стоимости объекта) размера фронта работ комплексного потока *F*, которая рассчитывается по величине оптимальной для данных условий производства строительных или реконструктивных работ, перерабатывающей способности станции *Nв*.

Разработаны основные варианты организации системы строительных потоков по критерию оптимального коэффициента совмещения, снижения себестоимости строительно-монтажных работ (текущие затраты *C*); эффективному использованию капитальных вложений в машины и механизмы (K_f единовременные затраты).

Предлагаемая методика выбора организационно-технологических решений предназначена для деятельности генподрядных и субподрядных организаций железнодорожного строительства; позволит снизить себестоимость строительно-монтажных работ, сократить сроки строительства и реконструкции железнодорожных станций.

КЛЮЧЕВЫЕ СЛОВА: железнодорожные станции; коэффициент совмещения; фронт работ; система строительного потока; перерабатывающая способность станций; формообразование комплекса работ; рациональный коэффициент совмещения; методика оптимизации; оптимизация организационно-технологических решений; технологическая компоновка; коэффициент совмещения потоков

Для цитирования: *Кабанов А.В., Маршавина О.А.* Разработка организационно-технологических решений по переустройству железнодорожных станций // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 5. https://doi.org/10.46684/2023.1.5.

INTRODUCTION

Modern methods of planning, designing and implementation of work on construction and development (or/and re-development) of railway stations and junctions are characterized by a variety of construction management and engineering solutions and the best ones are chosen [1–4] taking into account the following aspects:

- sequence of specific, facility-level and complex construction flows;
- phases of construction and separate commissioning of yards, tracks and station facilities;
- management and engineering solutions for the basic labour-intensive work on construction and upgrading of the earth bed, artificial facilities, water supply system, servicing facilities, railway automation and telemechanic devices, as well as the entire complex of track-laying and ballasting works;
- requirements to ensure safety of work and train movement on the construction site.

It is necessary to develop a methodology for management and technological planning of railway construction facilities to generate effective decisions on railway station reconstruction, reduction of the estimated cost of construction, optimization of construction time, reduction of construction work costs, and making better use of construction machines and transport.

MATERIALS AND METHODS

The materials used in the survey are the design documentation sections on construction and redevelopment of railway marshalling yards, design documentation on construction management plan (CMP), and complex management and engineering designs on the construction of complex facilities connected with train movement.

Marshalling yards are part of a large class of rail freight station systems designed to receive, handle and distribute freight car flows according to their destinations. The main components of such stations are receiving park (RP); sorting park (SP) and dispatch park (DP) [5, 6].

The sequence and phases of preparatory and main works is determined taking into account the working capacity of the station. The scope of works to be completed by a building contractor is substantiated so that the optimal working capacity of the station can be ensured.

During the construction and redevelopment of railway marshalling yards and phased commissioning of facilities, the work is carried out while trains are running on existing or new tracks [4, 7–9]. Specific and complex construction flows are grouped into the following types of works:

- construction of interconnection tracks;
- construction of new main tracks;
- extension of receiving-and-departure tracks;
- reconstruction of existing humps;
- construction of additional marshalling systems;
- laying of additional access tracks;
- reconstruction of turnouts and lead track switches;
- reconstruction and upgrading of railway automation and telemechanics systems (RAT) of receiving-and-departure tracks;
- construction and upgrading of power supply systems;
- reconstruction and upgrading of railway signalling (RAT) and humping equipment of marshalling systems.

The linear character of the facilities and continuous train movement can cause difficulties in delivery and storage of materials and machinery at the construc-

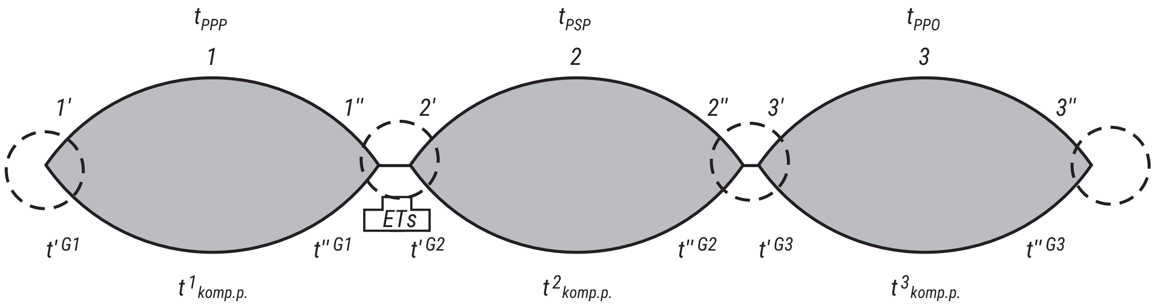

Fig. 1. Scopes of specific workflows during construction and redevelopment of a marshalling yard: 1' is entry neck of receiving park (switches, retarders); 1 is track structure (TS) of receiving park; 1'' is exit neck of receiving park; 2' is entry neck of sorting park (SP); 2 is TS of sorting park; 2'' is exit neck of sorting park; 3' is entry neck of departure park (DP); 3 is TS of departure park; 3'' is exit neck of departure park; t_G is duration of specific flow for neck construction; t_{PPP} is the time for laying TS of RP; t_{PSP} is the time for laying TS of SP; t_{PPO} is the time of laying TS of DP

tion site, hence making it difficult to use them at the scheduled time intervals. This complicates smooth construction workflows and entails downtime of works. It is also a managerial and technological challenge to estimate the exact scopes and terms of construction works when the railway station facilities are commissioned in phases [10, 11].

Volumes and scopes of specific and complex construction flows are grouped by railway marshalling yard components (*Fig. 1*).

Technological layout of specific construction flows includes:

- installation of switches and station neck tracks;
- laying station yard tracks;
- installation of railway automation devices and connection of necks and tracks to the electric interlocking system;
- construction of artificial structures;
- construction of electrification lines;
- construction of servicing and technical buildings.

$T_{sr.s.s.} = (t_{1komp.p.} + t_{2komp.p.} + t_{3komp.p.})K_s$ is the duration of complex construction or reconstruction flows of a marshalling yard and it is equal to the duration of construction flows of the receiving park (1), sorting park (2), and departure park (3) taken together taking into consideration the coefficient of construction sequence K_s

$$t_{1komp.p.} = t'_{G1} + t_{PPP} + t''_{G1};$$

$$t_{2komp.p.} = t'_{G2} + t_{PSP} + t''_{G2};$$

$$t_{3komp.p.} = t'_{G3} + t_{PPO} + t''_{G3};$$

$$K_S = [K_{Spp}; K_{Ssp}; K_{Spo}].$$

The scheduled time for the construction of a marshalling yard:

- t'_{G1} is the time of installation and laying the RP entry neck switches;
- t_{PPP} is the time of RP track laying;
- t''_{G1} is the time of installation and laying the exit neck tracks of the receiving park RP;
- t'_{G2} is the time of installation and laying the entry neck switches of the sorting park SP;
- t_{PSP} is the time of laying the sorting park tracks SP;
- t''_{G2} is the time of installation and laying exit neck tracks of the SP;
- t'_{G3} is the time of installation and laying the entry neck switches of the departure park DP;
- t_{PPO} is the time of the departure park tracks;
- t''_{G3} is the time of installation and laying of switches of the departure park.

The design of a complex construction flow for the construction or redevelopment of a marshalling yard should take into account the following specifics:

a) construction flows should not interfere with the main tracks and switches on the train routes across the station;

b) the station tracks and switches should be occupied for the shortest possible time;

c) extensive volumes of work should be divided into phases;

d) each phase should provide the optimal scope of uninterrupted work, comprehensive mechanization of construction, efficient use of machinery, and highly productive crews.

RESULTS AND DISCUSSION

The scope and type of each phase (scope of work) should be calculated in accordance with the general volume of main works on the station development, scheduled construction time and the minimal possible disturbance of the station's working capacity [12–15].

The studies (*Fig. 2*) conducted by the authors have shown that the optimal value (as a percentage of the total estimated cost of the facility) of the scope of complex construction work flow F is determined by the value of the optimal working capacity of the station N_P for given conditions of construction or renovation work.

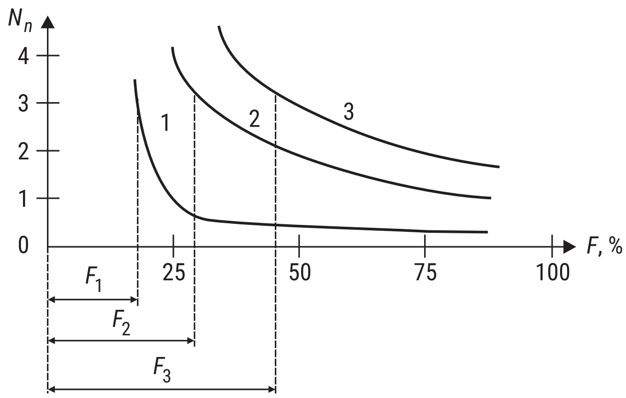

Fig. 2. Dependence of the railway station capacity (N_p, thous. carriages/day) on the volume of work scopes F of streamlined construction flows where F_1, F_2, F_3 are the scopes of preliminary construction workflows before reducing the working capacity of the corresponding stations (1 — during construction of railway marshalling yard; 2 — during reconstruction of stations equipped with hump and successive car distribution; 3 — during reconstruction of stations with parallel car distribution)

The specific construction flows include:

— specific construction flows for separate parks (with allocated work scopes within the corresponding park) including part of station necks;

— end-to-end specific construction flows.

Construction machines such as jib cranes and track-laying cranes for laying track switches and pre-assembled track lengths by elements and blocks can be a variable parameter. The sustainability of railway construction solutions is measured by the appraisal system with different variant parameters. This system includes natural, financial, managerial, technological and other performance criteria.

The analysis of the existing preparation work to be carried out for the railway station redevelopment shows that the standard technical specifications and different surveys describe separate factors without the relationship between them. Different options should be evaluated based not only on the technological work sequencing analysis (e.g., coefficient of construction flow sequence), but also on the financial analysis of the given facility construction. To design rational management and engineering models for the station redevelopment, it is necessary to identify and use these interrelated factors effectively.

Initially, the key model (with maximum scheduled time) is designed based on the standard input data, standardized time values and production flow charts for a certain type of construction. To manage railway construction more effectively, it is necessary to look for a variant with reduced construction time and an effective distribution of resources. Therefore, the initial data of the work time schedules as well as the management, engineering and economic indicators are adjusted to reduce the work scheduled time and make more effective utilization of the machinery, work force and financial resources.

Every next variant is designed based on the shortest possible construction time with the best possible workflow sequence, the highest possible rhythm of work and the maximum intensity of work without interruption. A shorter work production time with improved management and engineering indicators increases the concentration of capital investments in the construction of the facility and capital assets. However, a variant‘s productivity depends on the reduced costs of construction and installation works. At the same time, a variant's productivity may depend on different combinations of the calculated cost components.

After the work scopes and technological charts are established, different time schedules with the defined workflow sequence coefficients are drawn. They are:

- K_{srp} is the coefficient of work schedule sequence of the receiving park (RP);
- K_{srp} is the coefficient of work schedule sequence of the sorting park (SP);
- K_{sro} is the coefficient of work schedule sequence of the departure park (DP).

The optimal variant is one with the rational sequence coefficient of K_s. The key variants of construction flow management based on the optimal coefficient of workflow sequence, reduction of the cost of construction and installation works (current costs S), and effective utilization of capital investments in machines and mechanisms (one-time costs K_j) have been developed by the authors.

The value of the rational sequence coefficient for different management and technological charts (*Fig. 3*) corresponds to the intersection of dependence curves of current costs on the cost of works ($\Delta C_{1\text{-}j}$) and one-time costs in the form of capital investment ($\Delta K_{F1\text{-}j}$).

This graphic correlation gives a general understanding how to determine a rational management and technological indicator. In this aspect, several op-

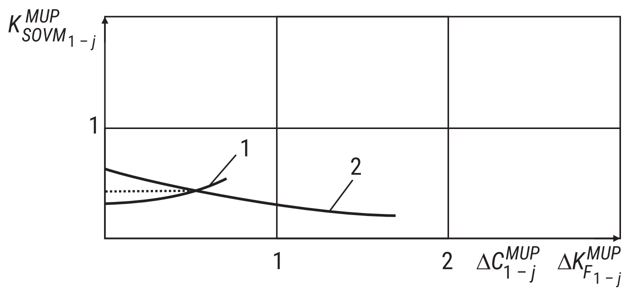

Fig. 3. Determination of the rational sequence coefficient: 1 is $K_{SOVM} = f(\Delta KF_{1\text{-}j})$; 2 is. $K_{SOVM} = f(\Delta C_{1\text{-}j})$

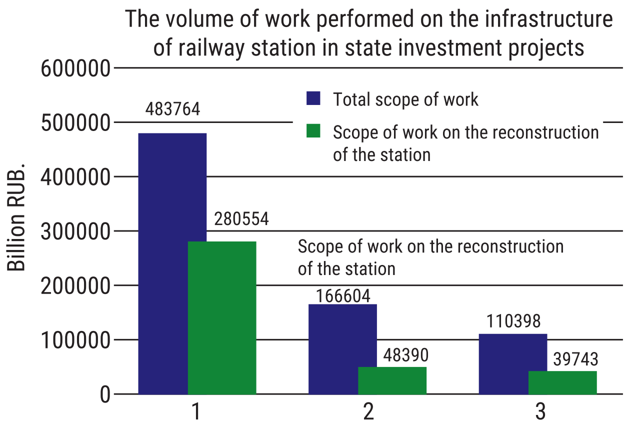

Fig. 4. Dynamics of investment in the construction and redevelopment of railway stations (investment projects of the railway infrastructure development): 1 — at the North – West ports approaches; 2 — at the the Azov – Black Sea ports approaches; 3 — at the BAM eastern part

tions of rational indicators can be determined depending on the components influencing the economic effect (e.g. reduced cost of work, reduced cost of capital assets, etc.).

The study showed that changes in management and technological indicators have the greatest effect on the change of construction and installation work costs (the correlation ratio is 0.802), particularly, such components as the cost of construction machine and device operation (the correlation ratio is 0.908) and the cost of production workers' wages and salaries (the correlation ratio is 0.807).

The schedul models for redevelopment and construction of station infrastructure within the state investment project of railway infrastructure development were analyzed. The volume and type of each phase (work scope) was established depending on the total volume of the station general development, specified construction time with the minimal disturbance of the station working capacity.

The proposed method for the station's management and technological optimization of construction is of current interest because national projects on railway transport development [1] envisage a large volume of work (30–40 % of the total) on the construction and renovation of station infrastructure facilities (*Fig. 4*). The efficiency of construction production management can be increased by defining a rational amount of resources within a limited work scope. Therefore, considering the increasing volumes of this type of construction, the proposed method will reduce the cost of construction and installation works, and shorten the time of construction and renovation of railway stations.

The dependence of management and engineering parameters on technical and economic parameters has so far been poorly investigated due to insufficient statistical data because of the difficulty of generating a large number of time schedule models. The proposed method for optimal work scheduling calculations uses the diagrams obtained from the Microsoft Project system, which makes it possible to automatically determine the variant's technical, economic, management, and engineering parameters given the specified scopes and resources. The variant's cost estimation can be imported with the help of the GOSSTROYSMETA cost estimate programme as it contains an MS Project estimate export.

CONCLUSION

The proposed method for management and engineering solutions is designed for general contracting and subcontracting railway construction companies. The above mentioned dependencies can be interpreted on the level of work production projects (WPP), work management projects (WMP) and construction management projects (CMP) based on different parameters. For example, at the WPP level, it is sufficient to use the parameter of cost changes in construction and installation works and capital investment changes in capital assets by changing management and engineering indicators. At the WMP level, the effect of early commissioning of a railway station facility should be taken into account. At the CMP level, the effect of capital investment distribution and the effect of early commissioning of the entire station complex into operation should be taken into account as well.

The analysis of time schedule models for reconstruction and construction of station infrastructure facilities included in the state investment project of railway infrastructure development at the North-West ports approaches showed that the cost parameters were reduced by 6–8 % of the total estimated cost of the facility. It was possible due to the use of the method of choosing the optimal work management model for marshalling yards. As the industry guidance documents have not been updated for a long time, the methodology presented in this paper can be of great practical importance.

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The authors declare no conflicts of interests.

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The article was submitted 14.07.2022; approved after reviewing 20.10.2022; accepted for publication 28.02.2023.

BRICS TRANSPORT
VOL. 2 ISSUE 1 2023

Original article
UDC 378:159.9
doi:10.46684/2023.1.6

Purpose in Life and Uncertainty Tolerance in Transport University Students during the COVID-19 Pandemic

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ABSTRACT In a situation of ambiguity and global crisis, uncertainty tolerance, purpose or meaning in life and life values have become important factors of psychological health and adaptability of the Transport University students. The purpose of this study is to survey the levels of students' uncertainty tolerance, purpose in life and life values.

Sixty students of Saint-Petersburg State Transport University aged 18–22 participated in the survey. The following methods were used in the research: Crumbaugh and Maholic's PIL (Purpose-in-Life Test) adapted by D. Leontyev; V.F. Sopov and L.V. Karpushina's Morphological Test of Life Values; E.N. Osin's adaptation of the McLane Uncertainty Tolerance Scale.

The Purpose-in-Life Test have revealed average scores; at the same time, high scores have prevailed on the "Locus of Control – Life" scale. The students' material and spiritual values proved to be in a good balance. The students' Uncertainty Tolerance turned out to be at an average level, but the "Uncertainty Tolerance" scale have revealed either high-level or low-level scores. Uncertainty tolerance is related to life values in both males and females. A higher purpose in life tends to promote greater psychological adaptability to ambiguous situations and boosts uncertainty tolerance in general. The females' uncertainty tolerance is connected to spiritual values, maintaining individuality, creativity, and hobbies. The males' attitude to novelty is linked to their prestige and achievement.

According to the survey, the Transport University students have an average level of uncertainty tolerance, purpose in life, and well-balanced material and spiritual values. Purpose in life is related to higher uncertainty tolerance and adaptability to ambiguous situation. There is some gender specific correlation between life values and uncertainty tolerance among males and females. Females' attitude is more related to spiritual values whereas males are more oriented to social success.

KEYWORDS: purpose in life; values; uncertainty tolerance; COVID-19 pandemic; students; Transport University

For citation: Yashchenko E.F., Sinelnikova E.S., Shumov M.E. Purpose in Life and Uncertainty Tolerance in Transport University Students during the COVID-19 Pandemic. *BRICS Transport*. 2023;2(1):6. https://doi.org/10.46684/2023.1.6.

Научная статья

Смысложизненные ориентации и толерантность к неопределенности в период пандемии у студентов транспортного вуза

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АННОТАЦИЯ В ситуации неопределенности и мирового кризиса толерантность к неопределенности, смысложизненные ориентации (СЖО) и ценностные ориентации становятся важным фактором сохранения психологического здоровья и адаптивности студентов транспортного вуза. Цель исследования — изучение особенностей толерантности к неопределенности, СЖО и ценностных ориентаций у студентов транспортного вуза, будущая профессиональная деятельность которых связана с высокой ответственностью, дисциплинированностью, способностью к устойчивой деятельности в стрессовых ситуациях.

В исследовании приняли участие 60 студентов ПГУПС в возрасте от 18 до 22 лет. Применялись методики: опросник СЖО Крамбо и Махолика в адаптации Д. Леонтьева, морфологический тест жизненных ценностей В.Ф. Сопова, Л.В. Карпушиной, шкала толерантности к неопределенности МакЛейна в адаптации Е.Н. Осина.

Выявлены средние показатели по методике СЖО, по шкале «Локус контроля — жизнь» преобладают высокие показатели. У студентов материальные и духовные ценности сбалансированы. Показатели толерантности к неопределенности у студентов находятся на среднем уровне, по шкале «Толерантность к неопределенности» преобладает высокий или низкий уровень показателей. Толерантность к неопределенности взаимосвязана с СЖО как у девушек, так и у юношей. Чем выше осмысленность жизни, тем выше психологическая адаптивность к неопределенным ситуациям и толерантность к неопределенности в целом. Толерантность к неопределенности у девушек взаимосвязана с ценностями духовного удовлетворения, сохранения индивидуальности, креативности и увлечениями, у юношей отношение к новизне связано с ценностями собственного престижа и достижений.

Студенты транспортного вуза обладают толерантностью к неопределенности, осмысленностью жизни, сбалансированностью материальных и духовных ценностей. Осмысленность жизни связана с более высокой толерантностью к неопределенности и адаптивностью к неопределенным ситуациям. Взаимосвязь ценностей и толерантности к неопределенности имеет гендерную специфику: у девушек выявлены взаимосвязи с духовными ценностями, у юношей — с ценностями социального успеха.

КЛЮЧЕВЫЕ СЛОВА: смысложизненные ориентации; ценностные ориентации; толерантность к неопределенности; пандемия; студенты; транспортный вуз

Для цитирования: *Ященко Е.Ф., Синельникова Е.С., Шумов М.Е.* Смысложизненные ориентации и толерантность к неопределенности в период пандемии у студентов транспортного вуза // Транспорт БРИКС. 2023. Т. 1. Вып. 1. Ст. 6. https://doi.org/10.46684/2023.1.6.

INTRODUCTION

At the turning points in history, prolonged uncertainty becomes an integral part of everyone's. The individual's spiritual resources become particularly important for positive coping. The works of W. Frankl (1990) and A. Langlais (2021) have shown the role of purpose or meaning in life in external and internal crisis. Life values are related to an individual's experience of internal (Okoneshnikova, 2012) and external life events. A study by E.V. Fedoseenko (2020) has revealed that the prevalence of altruistic values can be a resource for individuals in conditions that are perceived as threatening.

One of the biggest modern challenges people have faced worldwide was the pandemic of a new Coronavirus infection. The COVID-19 pandemic and vital threats and social constraints associated with it have had a negative impact on people's psychological health and emotional well-being. While fear was the most common emotional response at the early pandemic period (Seçer, Ulaş, 2020), anxiety, depression and stress increased later (Kavčič, Avsec, Kocjan, 2020; Talevi et al., 2020). Uncertainty tolerance developed as a result of less acute negative reaction to the pandemic (Pershina, 2022).

Young people make part of a vulnerable social group due to their lack of experience of crises and less social security than older and more mature people. At the early days of the pandemic, they had to adjust to the life with constraints including distant learning, which placed greater demands on their self-management. Researchers have identified factors that contributed to more successful adaptation and psychological well-being of students. Self-management and self-regulation boosted students' adaptation to new conditions and, consequently, they were more satisfied with life (Zinchenko et al., 2021; Sinelnikova, 2021).

In the post-pandemic period, higher education institutions including transport universities in the country returned to classroom learning, but the pandemic had a prolonged effect on students' emotional state and contributed to a higher level of mental stress that they were not always aware of. Chronic stress is potentially more dangerous to an individual's mental and physical health than acute stress unless the latter is fatal (Kitaev-Smyk, 2021; Sapolsky, 2015). Quarantine often has a delayed negative effect, particularly increasing the likelihood of post-traumatic stress even three years later (Reynolds et al., 2008).

After graduating from university, students will have to build their professional and personal life under conditions of uncertainty. Uncertainty tolerance becomes a key factor for psychological health as an integral component of an individual's psychological well-being (Pyatakova et al., 2019) and socio-psychological adaptability. As an essential trait in students, uncertainty tolerance helps to acquire professional knowledge and skills and develop a successful professional career as well as maintain psychological stability, which is important for transport workers.

Intolerance of uncertainty is associated with greater social anxiety and lower self-efficacy (Aksenova, Sineva, 2022). Purpose-oriented life (PIL) and meaningful life are personality factors contributing to successful coping (Odintsova, Semenova, 2011; Borisova, Shapovalenko, 2018) and their importance has increased in the current context. The data obtained from the students indicate that developed PIL is associated with a higher level of responsibility (Slotina, 2019) that is required in transport sector workers.

MATERIALS AND METHODS

Sixty students (24 males, 36 females) of Petersburg State Transport University (PSTU) aged from 18 to 22 took part in the empirical research. The following methods were used to collect the empirical data: Crumbo and Maholik's PIL Questionnaire (adapted by D. Leontiev, 2000), V.F. Sopov and L.V. Karpushina's Life Values Morphological Test (LVMT) (2001), McLane's Uncertainty Tolerance Scale (adapted by E.N. Osin (2010) [1–10].

RESEARCH RESULTS

The results of the PIL research are presented in *Table 1* and *Fig. 1*.

According to the survey results, the students in general showed mean PIL scores. However, on the "Locus

Table 1

Mean values according to D.A. Leontiev's Purpose-life Orientation Test

Scales	Mean	Standard deviation	Sample variance	Minimum	Maximum
Purpose	26,45	8,46	71,64	6	42
Process	22,42	5,67	32,11	9	32
Outcome	23,33	5,48	29,99	6	33
Control locus - I	19,05	4,44	19,74	8	26
Control locus - Life	27,18	6,68	44,59	8	39

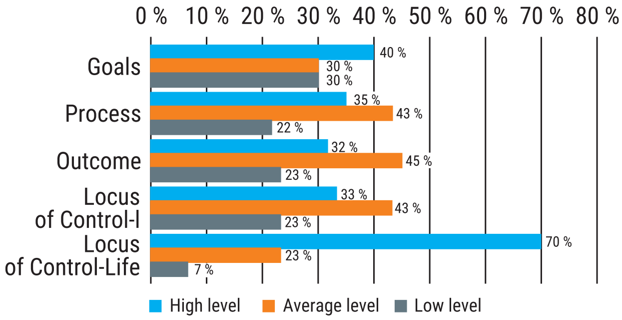

Fig. 1. Scores according to D.A. Leontiev's PIL methodology

of Control – Life" scale, 70 % of the Transport University students surveyed showed high scores, i.e. they are convinced that individuals can build and manage their life at their own will.

However, on the "Locus of Control – Self" scale, only 33 % of students show high scores, which means that most students are not confident in their ability to build and manage their life, and do not feel that they have sufficient internal and external resources to do so.

On the "Purpose" scale, 40 % of the students have high scores, i.e. they have purposes in life that they would like to achieve [11–15].

Only about one-third of the students have high scores on the "Process", "Outcome", and "Locus of Control – I" scales. This suggests that having formulated the goals, most of the students do not have practical tools to achieve them and to develop self-management skills, which is reflected in their life satisfaction (both process and results).

The results of the survey according to V.F. Sopov and L.V. Karpushina's LVMT methodology are shown in *Table 2* and *Fig. 2*.

Both material and spiritual values are obviously significant for the Transport University students.

The survey results according to the McLane Uncertainty Tolerance Scale adapted by E.N. Osin are shown in *Table 3* and *Fig. 3*.

The majority of respondents have shown average scores on all scales except uncertainty tolerance. On the "Uncertainty Tolerance" scale, high and low levels of tolerance predominate among the students.

There have been revealed certain relationships between the "Uncertainty Tolerance" and "Life Values" scales. The "Attitude to Novelty" scale correlates with self-esteem (r = 0.426, $p < 0.05$) and achievement (r = 0.503, $p < 0.05$) among young males. The young men's positive attitude to novelty depends on how high they value prestige and achievement.

The "Spiritual Satisfaction" scale correlates with the attitude to ambiguous situations (r = 0.380, $p < 0.05$), preference for uncertainty (r = 0.418, $p < 0.05$), with the overall Tolerance scale score of (r = 0.344, $p < 0.05$) among the females. When the girls are guided more

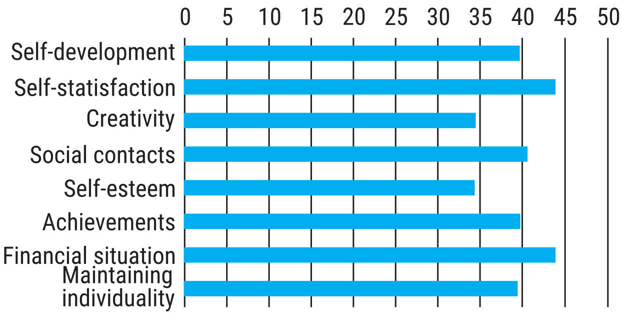

Fig. 2. Mean scores of the life value scales according to the LVMT methodology as adapted by V.F. Sopov and L.V. Karpushina

Table 2

Mean indicators of life values according to the "Morphological test of life values" method adapted by V.F. Sopov and L.V. Karpushina

Scales	Mean	Standard deviation	Sample variance	Minimum	Maximum
Self-development	39,65	7,68	58,94	17	60
Spiritual satisfaction	43,78	7,04	49,49	27	60
Creativity	34,40	8,82	77,74	15	60
Social contacts	40,35	7,49	56,06	22	56
Self-esteem	34,02	9,38	87,98	19	60
Achievements	39,78	7,19	51,73	20	60
Financial situation	43,82	7,12	50,73	27	60
Maintaining individuality	39,28	8,17	66,68	22	60

by moral principles in life, their attitude to ambiguous situations will be more positive. They will prefer the novelty to the familiar and their overall uncertainty tolerance will be higher.

"Creativity" correlates with the "Uncertainty Preference" scale ($r = 0.334$, $p < 0.05$) among the girls. The more important creativity is for the girls, the more they strive to develop their creative abilities and prefer the novelty to the familiar [16–24].

The "Individuality Maintenance" scale correlates with the attitude to challenging situations ($r = 0.388$, $p < 0.05$), attitude to ambiguous situations ($r = 0.344$, $p < 0.05$), and preference for uncertainty ($r = 0.364$, $p < 0.05$), with the overall score of ($r = 0.342$, $p < 0.05$) among the girls. When individuality and its manifestation in life are important for the females, they will be more positive to challenging and ambiguous situations. They will prefer novelty to the familiar and their overall uncertainty tolerance is higher.

The "Hobby" scale correlates with the attitude to ambiguous situations ($r = 0.381$, $p < 0.05$) and preference for uncertainty ($r = 0.385$, $p < 0.05$) among the girls. When interests and hobbies are important for girls, they will be more positive to ambiguous situations and their preference for novelty will be higher.

The survey has revealed the correlations between the "Uncertainty Tolerance" and "Meaningful Life" scales. The integrated "Meaning in Life" scale correlates with attitude towards novelty ($r = 0.433$, $p < 0.05$), challenge ($r = 0.424$, $p < 0.05$), and uncertainty tolerance ($r = 0.453$, $p < 0.05$), with the overall score of ($r = 0.446$, $p < 0.05$) among young men.

The more meaningful young men's lives are, the more defined their goals are and the more they experience the ontological significance of life. Thus, they are more positive to novelty and challenges and more adaptable to ambiguous situations. As a result,

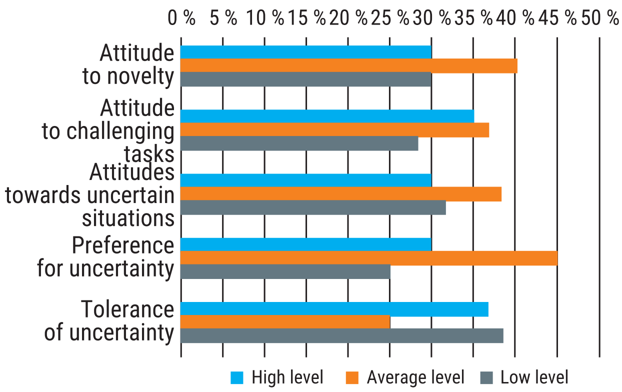

Fig. 3. Mean scores on the McLean Uncertainty Tolerance scales as adapted by E.N. Osin

Table 3

Mean indications in the McLane Uncertainty Tolerance Scale as adapted by E.N. Osin

Scales	Mean	Standard deviations	Sample variance	Minimum	Maximum
Attitudes towards novelty	12,72	2,92	8,51	7	20
Attitudes towards challenging tasks	29,82	6,04	36,49	19	45
Attitudes towards uncertain situations	34,32	7,75	60,05	17	56
Preference for uncertainty	42,22	8,06	65,02	27	66
Tolerance of uncertainty	38,42	9,05	81,98	19	57

they tend to view ambiguous situations as stimulating and emotionally charged and are more tolerant of uncertainty in general. Among the females, the "Meaning in Life" scale correlates with the attitude to novelty ($r = 0.397$, $p < 0.05$), challenging tasks ($r = 0.393$, $p < 0.05$), attitude to ambiguous situations ($r = 0.393$, $p < 0.01$), preference for uncertainty ($r = 0.411$, $p < 0.05$), and uncertainty tolerance ($r = 0.528$, $p < 0.01$), with the overall score of ($r = 0.501$, $p < 0.01$). The more meaningful the girls' life is and the more positive their attitude to novelty, challenges and ambiguous situations is, the more adaptable to uncertainty they are. Thus, their preference to novelty and uncertainty tolerance will be higher.

The "Goals" scale correlates with the attitude to novelty ($r = 0.356$, $p < 0.05$), ambiguous situations ($r = 0.479$, $p < 0.01$), preference for uncertainty ($r = 0.393$, $p < 0.05$), and uncertainty tolerance ($r = 0.424$, $p < 0.05$), with the overall score of ($r = 0.436$, $p < 0.01$). The girls' attitude to novelty and ambiguous situations will be more positive when their goals are more explicit and meaningful. They will prefer novelty to the familiar, and their adaptability to ambiguous situations and their uncertainty tolerance will be higher.

The "Life Process" scale is correlated with the attitude to novelty ($r = 0.502$, $p < 0.05$) and uncertainty tolerance ($r = 0.455$, $p < 0.05$) among the males. The more positive is their attitude towards novelty and the higher is their adaptability to ambiguity, the more emotionally charged and satisfied they are with their life. Among the females the Life Process scale is related to the attitude to novelty ($r = 0.374$, $p < 0.05$), attitude to challenging tasks ($r = 0.389$, $p < 0.05$), attitude to ambiguous situations ($r = 0, 548$, $p < 0.01$), preference for uncertainty ($r = 0.435$, $p < 0.01$), and uncertainty tolerance ($r = 0.514$, $p < 0.01$), with the total score of ($r = 0.506$, $p < 0.01$). The more positive is the girls' attitude to novelty, complex and ambiguous situations, the higher is their preference for novelty, their adaptability and uncertainty tolerance. As a result, they feel more emotionally charged and satisfied with their lives as being.

The "Life Outcome" scale is related to the attitude to novelty ($r = 0.348$, $p < 0.05$), challenging tasks ($r = 0.345$, $p < 0.05$), ambiguous situations ($r = 0.449$, $p < 0.01$), and uncertainty tolerance ($r = 0.498$, $p < 0.01$), with the overall score of ($r = 0.428$, $p < 0.05$) among the females. The more positive the girls are about new developments in their lives, the more they are willing to accept the complexity and ambiguity of the world and to take it into account in their actions. They are more adaptable to ambiguous situations and their uncertainty tolerance is higher in general. As a result, they perceive their life more meaningful and productive as being.

The "Locus of Control – I" scale is related to the attitude to novelty ($r = 0.445$, $p < 0.05$) and uncertainty tolerance ($r = 0.444$, $p < 0.05$) among the males. The more convinced the young men are of their ability to control their lives, the more positive they are to novelty and challenging tasks. Among the females, the Locus of Control – I scale is associated with the attitude to novelty ($r = 0.355$, $p < 0.05$), challenging tasks ($r = 0.385$, $p < 0.05$), and ambiguous situations ($r = 0.494$, $p < 0.01$) as well as preference for uncertainty ($r = 0.370$, $p < 0.05$) and uncertainty tolerance ($r = 0.511$, $p < 0.01$), with the overall score of ($r = 0.470$, $p < 0.01$). When the girls are more positive to novelty in life, they will more willingly accept the complexity and ambiguity of the world. They will prefer the new to the familiar; they will readily adapt to ambiguous situations, tolerate uncertainty in general and be more confident in their ability to control their own lives.

The "Locus of Control – Life" scale correlates positively with the attitude to novelty ($r = 0.428$, $p < 0.05$), challenging tasks ($r = 0.463$, $p < 0.05$), and uncertainty tolerance ($r = 0.414$, $p < 0.05$) among the young men. If the young men are more confident in their ability to control life, make decisions and put them into action, they will be more adaptable to ambiguous situations and more positive towards novelty and challenging tasks. Among the girls, the "Locus of Control – Life" scale is related to the attitude towards difficult ($r = 0.378$, $p < 0.05$) and ambiguous situations ($r = 0.455$, $p < 0.01$) as well as towards preference for uncertainty ($r = 0.363$, $p < 0.05$) and uncertainty tolerance ($r = 0.467$, $p < 0.01$), with the overall score of ($r = 0.443$, $p < 0.01$). The more confident the girls are in their ability to control their own lives, the more positively they accept the complexity and ambiguity of the world. They prefer novelty to the familiar and have higher levels of adaptability to ambiguous situations and uncertainty tolerance.

CONCLUSION AND DISCUSSION

The results of the research have shown that the majority of the Transport University students participating in the survey have well-balanced material and spiritual values and have an average score of purpose in life. According to the survey, 70 % of the students have high scores on the "Locus of Control – Life" scale. This means that a large proportion of the students believe in individuals' ability to control life. On the other hand, on the "Locus of Control – I" scale, the average scores prevail, i.e. the majority of students are less confident in their ability to control their lives, which could potentially be due to a lack of their planning and management skills. The research conducted earlier by the Applied Psychology Department at PGUPS suggests that planning, as a coping strategy, correlates positively with emotional comfort in students (Mazurova, Kaznacheeva, 2019). The Transport University students who developed self-management skills during the period of self-isolation and distant learning have a high level of satisfaction with life (Sinelnikova, 2021). The results of the empirical study conducted indicate that adaptability to uncertainty and readiness for new experiences are associated with higher scores on the "Locus of Control - I" scale, which means that the students' confidence in the ability to control their life is high enough in both males and females.

40 % of the Transport University students have high scores on the "Goals" scale, i.e. a significant number of students have formulated life goals. At the same time, satisfaction with both the outome and the process of life is at an average level. The "Process of life" scale is associated with the attitude to novelty and uncertainty tolerance among both males and females. The results of the empirical study suggest that the students' lack of satisfaction with life is partly due to internal psychological barriers, fear of ambiguity and the negative outcomes associated with it that prevent the students from having new experiences. The empirical research results (Kononova, 2014) also suggest that high school students involved in collective creative activities have higher "Purpose in Life" scale scores; they are more satisfied with the life process and its outcome and are more confident in their ability to control life as compared to the control group. A more active involvement of students, especially junior students, in the university social activities is likely to make students' life more meaningful, to develop their ability to control their life, and consequently, they will be more satisfied with life.

According to the survey, the uncertainty tolerance in the Transport University students is at an average level; nevertheless, on the "Uncertainty Tolerance" scale, low and high levels predominate. The research findings show that uncertainty tolerance is associated with purpose in life. A low level of uncertainty tolerance correlates with a lack of purpose in life, a lower level of confidence in their ability to control life and a lack of emotionally-charged and interesting life as being.

Thus, an average level of uncertainty tolerance can be assumed as optimal. Public sector workers with a low level of anxiety and pronounced temporal infantilism have a higher level of uncertainty tolerance compared to those with an average level of anxiety and temporal freedom (Dukhnovsky S.V., 2022). The average scores on the "Uncertainty Tolerance" scales suggest that the Transport University students accept ambiguous situations in general and are willing to undertake challenging levelsf tasks. They are moderately positive to novelty, are highly reflective and relatively quick to move from plans to action, and have a moderate ability to take risks. A low level of uncertainty tolerance revealed in a third of the students surveyed can potentially reduce their psychological adaptability to ambiguous situations. The gender differences in uncertainty tolerance have revealed that uncertainty tolerance in males correlates with social success, whereas in females — with moral values, creativity and hobbies.

In conclusion, it can be stated that the Transport University students possess well-balanced material and spiritual values, a well-developed sense of life purpose and a high level of uncertainty tolerance. Purpose in life is associated with higher uncertainty tolerance. The students with the defined life purposes are more tolerant of uncertainty. They readily learn new skills and solve challenging tasks, and are prepared to live and act in uncertain environments.

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Contribution of the authors: the authors contributed equally to this article.
The authors declare no conflicts of interests.

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The article was submitted 17.01.2023; approved after reviewing 08.02.2023; accepted for publication 28.02.2023.

Original article
UDC 656.2
doi: 10.46684/2023.1.7

The analysis of modern diagnostic and monitoring devices for the traction power supply system

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ABSTRACT While developing a new modern device for diagnostics and monitoring of the grounding system in real time, the existing modern devices for diagnostics and monitoring of the railway traction network have been analyzed and specific features of high-speed rail traffic development have been studied. The paper presents the existing devices and methods for diagnostics and monitoring of the power supply elements of railway traction. The basic principles of operation of the devices used are given and their advantages and disadvantages are analyzed. The presented analysis makes it possible to estimate the new tendencies in diagnostics and monitoring system development and to summarize further prospects of their implementation and improvement.

KEYWORDS: monitoring; grounding; diagnostics; grounding system of contact line poles; traction power supply; high-speed transport; low-maintenance system.

For citation: Agunov A.A., Terekhin I.A., Stepanskaya O.A., Baranov I.A., Abishov E.G. The analysis of modern diagnostic and monitoring devices for the traction power supply system. *BRICS transport*. 2023;2(1):7. (In Russ.). https://doi.org/10.46684/2023.1.7.

Научная статья

Анализ современных устройств диагностики тяговой сети высокоскоростного железнодорожного транспорта

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АННОТАЦИЯ В процессе разработки нового современного прибора диагностики и мониторинга в режиме реального времени системы заземления для учета существующих особенностей развития высокоскоростного движения проведен анализ современных устройств диагностики тяговой сети железнодорожного транспорта. Представлены имеющиеся устройства, методы диагностики и мониторинга элементов тягового электроснабжения железных дорог. Отражены основные принципы работы применяемых устройств, а также проанализированы их преимущества и недостатки. Выполненный анализ позволяет судить не только о тенденциях развития систем диагностики и мониторинга, но и сделать выводы о дальнейших перспективах их внедрения и доработки.

КЛЮЧЕВЫЕ СЛОВА: мониторинг; заземление; диагностика; система заземления опор контактной сети; тяговое электроснабжение; высокоскоростной транспорт; малообслуживаемая система

Для цитирования: *Агунов А.В., Терёхин И.А., Степанская О.А., Баранов И.А., Абишов Е.Г.* Анализ современных устройств диагностики тяговой сети высокоскоростного железнодорожного транспорта // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 7. https://doi.org/10.46684/2687-1033.2023.1.7.

INTRODUCTION

Based on the "Strategy for the Development of Rail Transport in the Russian Federation up to 2030", Russian railways have been concentrating their efforts on the extension of high-speed traffic, increase of train weights and improvement of reliability of the current collection system. The risks of traction network failures increase with the increase in speeds; train traffic disruptions lead to significant economic losses. Repair works take a considerable amount of time, as the damaged sections become more extensive. The standard way of ensuring high reliability factors is providing redundancy and increasing the safety margin. So, at speeds over 160 km/h, it is forbidden to operate the contact wire with wear and tear exceeding 20 % of the nominal cross section. At the same time, on the lines with low speeds, the 30 % wear is allowed. A similar situation is with the tension of contact wires and cables in the catenary suspension system. Despite the positive effect of increased wire tension on the quality of current collection, it is limited to about 50 % of the yield strength of the material.

The factors described above have led to the situations when the contact wires have to be replaced long before reaching their critical wear and tear nowadays, thus, leading to a decrease in the dynamic performance of the current collection system. The problems related to the increase of permissible speeds and service life of contact wires in conditions of high-speed traffic are acute and should be taken into consideration when designing high-speed lines.

In operation, the contact line adjustment characteristics specified by the project are capable of exceeding the permissible values due to the electric rolling stock impact (ERS), climatic conditions and current loads and all this can lead to failures. To ensure quality and reliable current collection, it is necessary to constantly monitor the state of the contact line and traction network as a whole. Improvement of contact line operation technologies using the permanent diagnostics and monitoring systems helps to reduce the need for JSCo "Russian Railways" in traction network elements with increased strength characteristics as well as to increase their life service and allow high-speed train movement on conventional rail sections.

Under the "Strategy for Scientific and Technological Development of the Russian Railways Holding Company for the period up to 2025 and for the perspective until 2030", one of the most important tasks in rail transport is to improve the quality of the traction network maintenance through the use of software and hardware complexes. They will enable the monitoring and diagnostics of traction network elements in an autonomous mode.

Autonomous diagnostic and monitoring devices integrated into the whole system will improve the quality of diagnostics and monitoring, as well as reduce the need for highly qualified personnel and virtually eliminate the human factor (Burkov, 2021).

MATERIALS AND METHODS

Traction network monitoring and diagnostic devices can be divided into mobile and stationary ones. Mobile devices are a laboratory wagon and various manual devices for control of traction power supply system elements. Stationary devices are used for continuous monitoring of certain parameters in real time. The information from stationary devices is transmitted via various communication channels, such as optoelectronic and radio channels, mechanical (via insulating element), and optical. Processing and analysis of output signals from the sensors installed on traction network elements are performed according to specially developed algorithms for each of them and the program responsible for combining, storing and transmitting these signals.

Mobile Diagnostic Devices

The problem with using mobile devices is that they have to perform diagnostics on operating lines with electric trains constantly running. In addition, manual measurements aren't sufficiently effective since they require patrolling of the monitored sections of different lengths and do not give accurate data.

One of the most effective mobile devices is an automated control system of contact line parameters. They are installed in a diagnostic laboratory wagon, on the

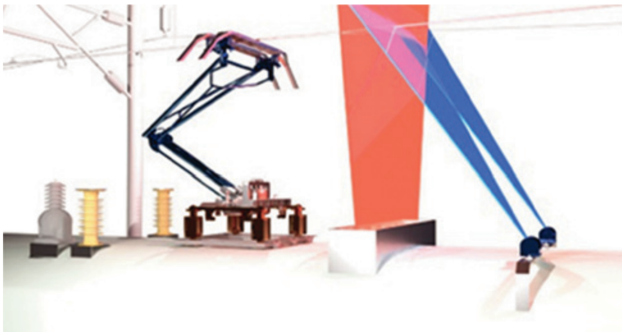

Fig. 1. System for speed control of contact wire

roof of which a measuring current collector and an observation tower with measuring equipment are mounted. Besides determining the type and magnitude of the voltage used in a contact line, the special devices make it possible to measure and register the deviations of the contact line parameters beyond normal for all the contact line facilities. Thus, they automatically generate a report on the assessment of the technical condition of the contact line on the monitored track section. The design of the observation tower provides a wide and sufficient view for the measuring and control systems installed on it for video and thermal monitoring as well as ultraviolet diagnostics.

The system of fast control of the contact wire[1] [1] (*Fig. 1*) is one of the modern developments. The sensors take all measurements in a non-contact manner, and the measurements are taken at the level of railhead top in relation to their location in the section. Simultaneously, the computer system devices register the lowered position of the contact wire on aerial frogs and the height of the clips set relative to it. They also measure the force of current collector pressure on the contact wire as well as register shocks to the current collector, contact wire tension and current collector skid breaks off. The diagnostics data with the registered deviations from the required standard parameters of the contact line are displayed in the form of graphs on the monitors of the operator's computer system that are saved on the computer storage devices. The measurements from the thermal imaging and UV camera are recorded separately. All recorded readings are integrated with the recorded parameters of train speeds and the distance travelled in the sensors as well as in the points of contact wire fixation.

Stationary Diagnostic Devices

The JSCo "Russian Railways" testing ground railway has been widely using the stationary diagnostic and remote monitoring system (SDRM) of the contact line. It includes various sensors for recording the parameters of the technical condition of the contact line elements consisting of a carrying cable (CC), contact wires (CW), consoles, strings, and load-compensating devices placed on the anchored poles of the contact line. The stationary data acquisition and transmission devices are installed along the entire length of the contact line section on the CC and CW behind the rollers of the load-compensating units and/or above the load-compensating unit placed on the anchored poles of the contact line (*Fig. 2*). Each device for collecting and transmitting information has a set of sensors for measuring the parameters of the technical condition of the contact line elements, a microprocessor device for analog-digital processing of the sensors' information, an autonomous power supply, a device for wireless communication between the device and an intermediate information storage device SDRM placed at the nearest station. The latter is connected with a single storage device collecting information about the contact line elements of the railway network by wire and/or wirelessly [2].

However, the stationary devices have not been installed yet due to certain difficulties. In order to control the parameters of the contact line for detecting pre-failure conditions, it is planned to use a combined monitoring and diagnostic system consisting of mobile diagnostic devices (laboratory wagons), diagnostic tools on the ERS, and stationary monitoring devices installed along the entire line section as well as a single system for data collection and analysis. The stationary devices provide diagnostics and monitoring of a number of pa-

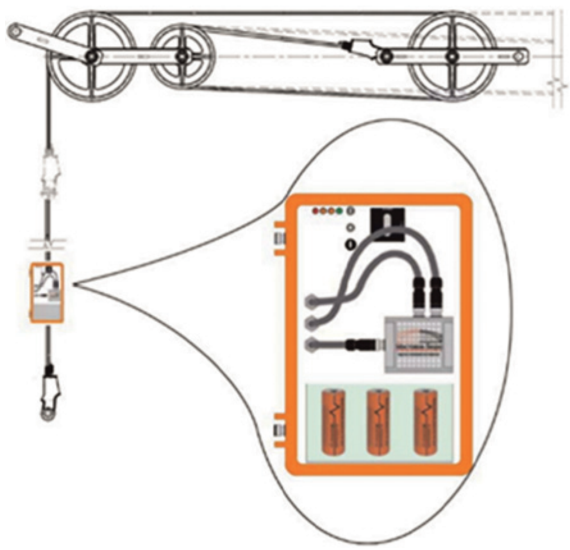

Fig. 2. Information collection and transfer device SDRM

[1] Contact Network Control Systems. URL: https://tvema.ru/625 (In Russ.).

rameters, for example, the displacement of compensating weights, tension of contact suspension wires, temperature of contact wires, ice formation, vibration, and inclination of contact line poles, etc.[2].

Results and discussion

The main disadvantage of the existing systems for monitoring the contact line condition with the help of mobile diagnostic devices is that these measurements are carried out periodically, and the monitoring time is short enough, which does not provide a constant control of the stress-strain behaviour of the contact line elements. In addition, the optical devices do not provide very reliable data.

The continuous monitoring systems that are used do not allow assessing the tension of wires and cables of the traction network in online mode; otherwise, they require corrections in the construction of the monitored facilities.

Both versions of diagnostic and monitoring systems can control only one parameter — the strain in wires and cables. In addition, the described systems do not provide continuous diagnostics and monitoring of the behaviour of traction network elements. Most importantly, they do not provide real-time prediction of pre-failure and failure situations. Currently, many of these disadvantages have been solved in the recent developments [3, 4]. However, further improvements are required before the new system can be installed. Along with the development of the optimal system for diagnostics and monitoring of the contact suspension elements, the issue of diagnostics and monitoring of other elements in the traction network, in particular, such an important element of traction power supply as the grounding system, remains unresolved.

According to (Ministry of Railways of Russia, 1993) (*Table*), it can be concluded that the frequency of checking the grounding system devices is not as required and consists mainly of visual inspections. That combined with the human factor creates a high probability of not detecting the faults in the grounding system beforehand.

This maintenance procedure inevitably involves high labor costs of its implementation, and often does not detect the real pre-failure states of the grounding system elements. This leads to failures and, consequently, to disruptions in train traffic, and in the worst cases, can lead to disasters.

One of the important and problematic issues is the resistance of the contact line poles groups, which affects the operation of the relay protection.

Operational information about the technical condition of the traction network elements including the grounding system will allow technicians to eliminate pre-failure conditions in time.

Currently, only the railway automation and telemechanic facilities are equipped with the devices of continuous diagnostics and monitoring as less than 3 % of failures leading to disruption of train traffic and risking safety of people registered are caused by them [5, 6]. However, the traction network and railway track facilities are to be equipped by continuous diagnostics and monitoring devices as they are not redundant.

It has been a long-time necessity to introduce continuous monitoring and diagnostic systems of the traction network on railways as failures of traction network elements lead to disruption of train traffic, threaten the safety of passengers and maintenance personnel, and have a negative effect on adjacent facilities.

It should be noted that the cost of implementing the monitoring and diagnostics system is supposed to be less than 10–15 % of the cost of capital construction of the traction network according to a preliminary estimate. The cost of the diagnostics and continuous monitoring system can be divided into two components: the cost of technological equipment such as sensors, accumulators, autonomous power supplies, etc. and the computer centre of the complex including data transmission channels, automated workplaces, servers, etc. Application of the continuous monitoring and diagnostics system will contribute to almost complete elimination of critical damage of traction network elements leading to a threat to human safety and disruption of train traffic.

Obviously, the quality and safe operation of electrified railways directly depends on the reliable operation of all components of railway infrastructure and ERS. Thus, the system of continuous monitoring and diagnostics of railway infrastructure facilities including grounding systems is an effective means of ensuring high reliability as well as forecasting pre-failure conditions.

The specialists of the "Electric Power Supply of Railways" Department at the Emperor Alexander I St. Petersburg State Transport University are working on the development of a new diagnostic and monitoring device for the grounding system in real time. In combination with the traction power supply system without grounding the contact line poles on the traction rail, this device will create a low-maintenance grounding system and allow for control within the digital substation.

[2] Innovative Contact Network Solutions for High-Speed Lines. URL: http://eav.ru/publ1.php?publid=2017-11a04 (In Russ.).

Table

Frequency of inspections, checks and measurements of grounding devices

Name of work on the scope of maintenance for grounding devices	Periodicity
1. Inspection of all visible grounding system elements, checking tightness of contacts, the integrity of the installation, absence of mechanical damage; tightening of loose bolted contacts, elimination of detected faults	Twice a year (spring and autumn)
2. Selective opening of the ground to inspect grounding elements in the ground	once every 5 years
3. Measuring the resistance of the grounding device (if it's value is rated)	After installation, not later than 6 months after commissioning, and thereafter at least once every 3 years
4. Measuring the grounding resistance of structures and devices connected to the rail circuits (if necessary to monitor their values with regard to their influence on the operation of signalling circuits and protection against electrical corrosion)	During commissioning and thereafter at least once every 5 years (for direct current) and at least once every 10 years (for alternating current)
5. Checking serviceability of protective devices of the grounding circuit: airgap diode, diode-spark grounders airgap type IPV-CNII	 once every 3 months twice a year once a year
6. Checking the serviceability of the grounding circuits by electrical measurement	once a year

CONCLUSION

Development of the real-time diagnostics and monitoring system for the railway traction network goes hand in hand with the improvement of monitoring technologies, reduction in the computer system cost and an increased level of the system operation quality. Additionally, the equipment of railways with continuous monitoring systems creates favorable conditions for the development of digital railway space or digital railway [7].

The development of data transmission networks with signal-transmitting elements included in the diagnostic devices of the permanent traction network monitoring system on long railway sections boosts the development of diagnostic information wireless transmission system in real time. Any diagnostic and monitoring devices for the railway infrastructure, including grounding systems equipped with radio transmitters can be connected to such a system. This would not require the provision of counterpart services in terms of communication [8]. At the same time, a real-time digital diagnostic data transmission system will allow the use of cloud-based storage and transmission technologies on the railway transport. For example, the nearest service personnel can transmit the diagnostic and monitoring data by means of portable devices to the diagnostic and monitoring facility. Stationary workplaces with a large number of hardware and computers will not be required, and the monitoring data can be integrated into a separate module of the automatic train control system. The reduced equipment will cut the cost of diagnostics and monitoring systems for various railway infrastructure facilities. However, scientists engaged in the development of continuous monitoring systems for railway infrastructure facilities have not yet been able to solve the problem associated with the use of diagnostic data not only for maintenance tasks but also for transferring information about deviations from the standard indicators on the on-board units of the EPS. This would allow taking the right decisions in conditions of critical violations of train safety to counteract dangerous situations, from a lowered pantograph in dangerous areas to a complete train stop.

The development of the continuous monitoring and diagnostics system for controlling railway traction network elements have shown the prospects of its widespread implementation as well as the possibility of using Smart grid technology, that is smart power supply networks [9].

The development of continuous traction network monitoring technology, as well as the creation of low-maintenance diagnostic tools, will enable the optimization of all electrified railways in the future.

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Bionotes

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The authors declare no conflicts of interests.

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The article was submitted 30.12.2022; approved after reviewing 30.01.2023; accepted for publication 28.02.2023.

BRICS TRANSPORT
VOL. 2 ISSUE 1 2023

Original article
UDC 656.07:164
doi:10.46684/2023.1.8

Tendencies, expectations of shippers and solutions of operators in the transport market of the Republic of Kazakhstan

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ABSTRACT The article considers the main stages of development of the transport and logistics market, analyses changes in the supply chain and market trends, reveals their impact on acceleration of digitalization processes, reveals measures to reform the railway industry, noted the development of the new Eurasian logistics infrastructure, summarized the results of Kazakhstan's foreign trade for 2022, showed opportunities for the development of alternative transport corridors and infrastructure facilities, as well as directions of private investments of residents of the economies of Kazakhstan and neighboring states (China, Kyrgyzstan, Uzbekistan) in the development of its transport infrastructure and logistics, foresight for business for the next 10 years is given.

KEYWORDS: development; transport; logistics; market; supply chain; digitalization; reform; railway; infrastructure; trade; transport corridor; investment

For citation: Kobesov K.K., Kurenkov P.V., Ivanov A.P., Onufrieva M.A. Tendencies, expectations of shippers and solutions of operators in the transport market of the Republic of Kazakhstan. *BRICS transport*. 2023;2(1):8. https://doi.org/10.46684/2022.1.8.

Научная статья

Маркетинговые исследования и анализ рынка транспортно-логистических услуг в Республике Казахстан

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АННОТАЦИЯ Рассмотрены основные этапы развития транспортно-логистического рынка, проанализированы изменения в цепочке поставок и рыночные тенденции, раскрыто их влияние на ускорение процессов цифровизации. Показаны мероприятия по реформированию железнодорожной отрасли, отмечено развитие новой евразийской логистической инфраструктуры, приведены итоги внешней торговли Казахстана за 2022 г. Приведены возможности развития альтернативных транспортных коридоров и инфраструктурных объектов, а также направления частных инвестиций резидентов экономик Казахстана и сопредельных государств (Китай, Кыргызстан, Узбекистан) в развитии своей транспортной инфраструктуры и логистики, дан форсайт-прогноз для бизнеса на предстоящие 10 лет.

КЛЮЧЕВЫЕ СЛОВА: развитие; транспорт; логистика; рынок; цепочки поставок; цифровизация; реформирование; железная дорога; инфраструктура; торговля; транспортный коридор; инвестиции

Для цитирования: *Кобесов К.К., Куренков П.В., Иванов А.П., Онуфриева М.А.* Маркетинговые исследования и анализ рынка транспортно-логистических услуг в Республике Казахстан // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 8. https://doi.org/10.46684/2023.1.8.

INTRODUCTION

The Asian region now has significant human and natural resources. Of the world's 30 largest cities, 21 are in Asia. It is expected that of the estimated 30 trillion dollars of growth in middle-class consumption by 2030, only one trillion dollars will go to the Western economies. At the same time, the future of Asia itself depends on the collective will to strengthen dialogue among the cultures, traditions and world views of the peoples of the region.

CARGO MARKET

The Republic of Kazakhstan (Kazakhstan), which is a part of the world market of logistics services (RLU), has come a long way in the last 30 years. From *Fig. 1*, which presents the main stages of development of the transport and logistics market, it follows that during the period 1991–2022, this market has developed rapidly.

This was due to the following circumstances:

Firstly, the state created conditions for the development of a competitive environment and private initiative in the segment of operating freight wagons. Freight forwarding, customs brokerage companies began to appear actively. In the middle of the 2000s there was a boom on the wagon companies. Zh.-d. the administrations of Russia, Ukraine and Kazakhstan have transferred the fleet of MEAs wagons to the ATP park. There was a pool of private investors who invested in their own cars. Today in Kazakhstan about 135 thousand private cars (more than 75 % in the structure of the car park of the country). They are owned and operated by dozens of owners — from large to small companies, private individuals. A truly highly competitive RLU has appeared in this segment. Tens of thousands of new jobs have been created.

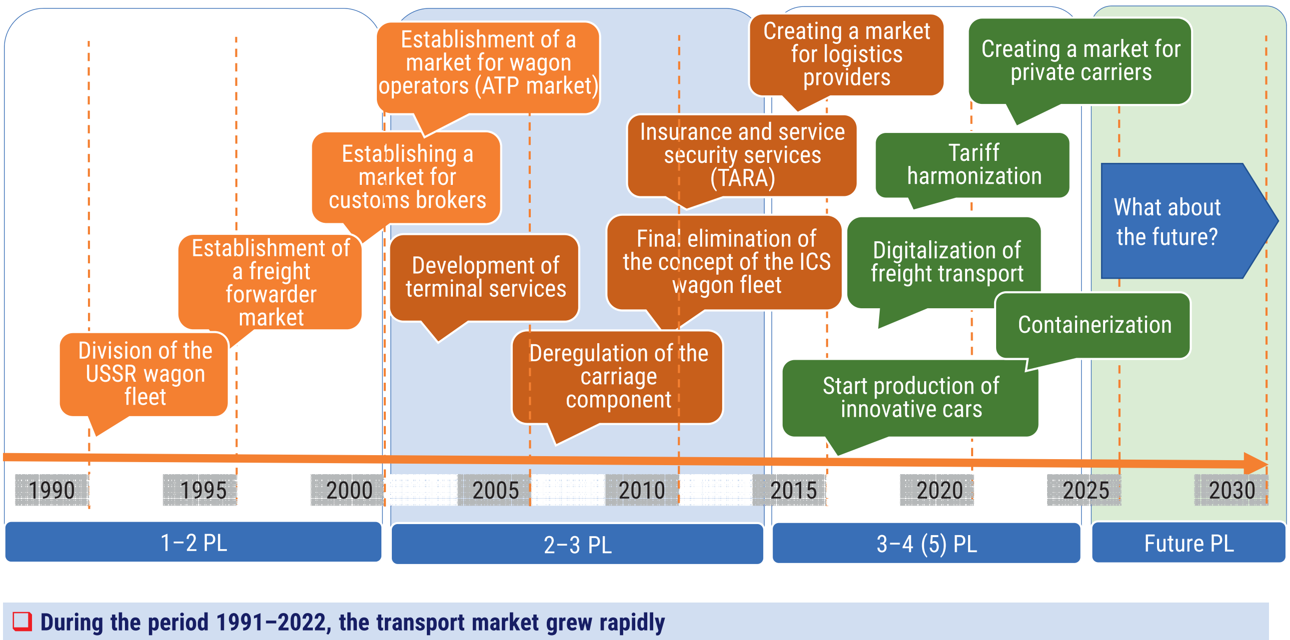

Fig. 1. The main stages of development of the transport and logistics market

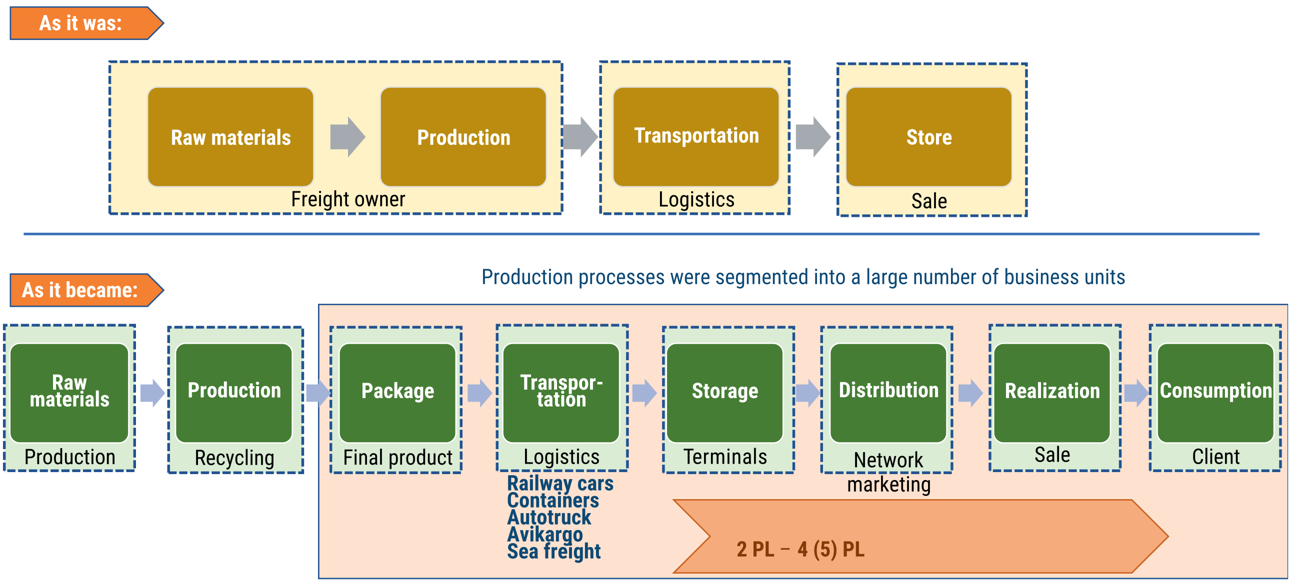

Fig. 2. Developments in logistics (supply chains)

Secondly, amendments and additions were made to the Legal Acts regulating the work of railway (Zh.-d.) transport, which opened up opportunities for access to the main railway. Network of private cargo carriers and promotion of competition. For example, in May 2018 in Kazakhstan, two private carriers began transporting goods using their own locomotives, along with the National Cargo Carrier "Cossack Temir Zholy". At that time, private carriers were completely new participants of RLU.

Thirdly, digitalization of logistics has been actively developed, issues of containerization have moved to a more active stage, and innovative direction has started to develop.

In the USSR supply chains were quite simple (see *Fig. 2*). Logistics was not considered in conjunction with the sale of goods and services, and the associated and indirect costs were not considered.

Since the 1990s, logistics has been integrated into all industries and economies. Production processes have been segmented and detailed into smaller business processes. This period is characterized by the search for new solutions in the field of reducing costs (logistics costs) in production, distribution, sales and delivery. Modern automated warehousing complexes have been formed and containerization of freight transport has been actively used.

The application of uniform packaging and packaging standards in distribution logistics systems has had a significant economic impact.

The functions of enterprises and partners in logistics business are segmented into a single logistics chain (i.e.: procurement — production — distribution and sale).

The IT revolution and the introduction of personal computers have also influenced the development of a new logistics vector. State-of-the-art software enabled the use of computers ranging from the procurement process to the distribution and sale of the finished product.

The volume of logistics services transferred to outsourcing 2.3PL to operators and to operators 4–5PL is increasing.

And it is expected that this trend of doing business will only gain momentum in the future.

Aware of the enormous contribution of logistics to the profitability of business processes, business owners increasingly have to turn to logistics experts.

This shows good prospects for the development of logistics in general.

In recent years, the construction of high-tech warehouses of the full cycle has been growing, order in the transport sector has been brought to the legislative level, and programmes for automation and optimization of logistics processes have been produced.

Customers are provided with quality service and optimization of their logistics processes.

As we see from the history of the formation of transport logistics, this industry is actively developing and growing, and large companies no longer represent their business without the help of a logistics operator.

International companies and large firms separate special services, departments, departments or logistics sectors.

The main function of most companies was to reduce the cost of goods and to use raw materials, semi-finished products and components more efficiently.

CHANGES IN THE SUPPLY CHAIN HAVE GIVEN IMPETUS TO THE DEVELOPMENT OF LOGISTICS

The growing needs of the business environment led to the need to create and develop service companies that provide a full range of services from the initial consignor to the final recipient.

On the radar other than aviation, water, etc. Project logistics and project management, multimodal transport involving two or more modes of transport have emerged.

Thus, not only the technological but also the commercial and financial role of radar transport has been recognized.

There are new professions in demand:

- IT operators in logistics;
- dispatchers — aggregators;
- developers and technologists of logistics solutions;
- coordinators;
- integrators;
- suppliers of all kinds etc, which creates new jobs.

The development of world integration processes has contributed to the creation and development of intermodal and multimodal logistics companies.

A new paradigm of international trade has been established, migration has increased, and there has been an exponential increase in freight turnover, vehicle fleet and world transport and logistics infrastructure. The business level of the transport and logistics complex has increased. It develops as a result of the growth of production and consumption, while giving new impulses to the integration of production processes, distribution, marketing and delivery of products, their logistics, which allowed planning and delivery from anywhere in the world.

Manual processing of goods and documents predominated in all the authorities involved:

- customs clearance;
- phytosanitary design;
- registration of transport documents;
- registration of the origin of the goods;
- payment of the tariff and related services;
- insurance of goods etc.

The current world trends have influenced the acceleration of digitalization processes, electronic document circulation has been introduced everywhere.

In the beginning there were the usual simple digital solutions, then went more extended and deeper software products.

Electronic transport is now used instead of traditional paper transport documents. The software system is good because, sitting in the office at the workplace, any employee can submit documents for approval and track their progress through a single electronic database.

If previously, when approving letters, protocols, telegrams and other documents had to go through a series of offices until they reach the table of the station chief or other structural unit, now this procedure has been simplified and is carried out at an accelerated pace, without delay.

Due to this, the consumer of transport and logistics services has the opportunity to use the high speed of processing of goods and accompanying documents, mobility and transparency of their preparation, registration and passage.

There are many digital platforms and services that allow providing services to clients in one click.

Users of these programs can access applications from any device, whether mobile phone or computer.

The most important thing is to eliminate human contact as much as possible.

Various digital platforms created by different tools between RLU actors in different countries are being integrated.

In addition, the pandemic has changed a lot in the logistics space, as a result of the trend of digitalization (digitalization) has only intensified.

The share of e-commerce and marketplaces as well as automation and robotization of warehouse operations can be noted.

Further development of logistics contributes to creation of amazing and useful digital developments.

In the period 2000–2020, the Government of Kazakhstan has carried out several programs of reform of railways.

In general, the reform of railways was aimed at improving the efficiency and quality of services through liberalization, private initiative and investment.

The Government of the Republic of Kazakhstan has adapted the approach adopted in the European Union, consisting of vertical division. infrastructure and transportation, development of competition.

During this time, a relevant legal and regulatory framework has been established for carrying out the fundamental changes reflected in the policy documents on the reform. industry, corporate strategy and legislation, including organizational separation of transport activities and infrastructure.

Implemented measures:

— amendments and additions to international treaties on the functioning of transport in the EEA;

— harmonization of tariffs for the carriage of goods by type of communication;

— large-scale investment program for renewal of rolling stock and construction and modernization of infrastructure;

— initiation of work on introduction of a new mechanism of subsidy of losses of carriers, carrying out the following passenger transport on socially significant inter-regional communications;

— development of the industry of transport engineering;

— intensive development of logistics and multimodal transit transport.

In his recent address, the President of the Republic of Kazakhstan K-J. K. Tokayev stressed that the development of the new Eurasian logistics infrastructure is one of the important priorities.

The Head of State noted the importance of joint development with the participating countries of international transport corridors (MTC) in terms of ensuring freedom of transit of goods, creation of new and modernization of existing MTC.

Taking into account the tasks set by the state, the further business strategy envisages growth in the segment of transit and multimodal transport and logistics services through:

- development of new competencies and integration of services into a single logistics service;
- entering new segments of the radar and offering new transport "products";
- modernization of transport infrastructure; establishment of the internal and external TLC network;
- development of the dry cargo fleet;
- forming partnerships and alliances;
- the institutional development of ITC.

In order to ensure the full development of the transport and transit potential of the country in accordance with the instruction of the Head of State, the sectoral Ministry, together with business, is developing a concept for the development of transport and logistics potential of the country until 2030, which will form a new conceptual framework for the development of transport and logistics complex, taking into account the growing requirements for competitiveness and quality of services.

Foreign trade conditions were favourable for Kazakhstan in 2022. The main markets for Kazakh products are China, Italy and Russia.

Merchandise exports rose by 53 % to $48.9 bn, while imports grew by 14 % y/y to $25.4 bn.

Total turnover rose by 37 % to over $74 billion.

There was a significant increase in deliveries to the EU and China.

More than half of Kazakhstan's output was exported, with processed goods accounting for one third of total exports.

The number of countries receiving Kazakhstan's exports has increased, i.e. the number of commodity markets has increased from 112 to 118.

Positive trade results are directly related to the current expectations of shippers.

The main criteria are traditionally (see *Fig. 3*):

- availability of services;
- customer focus;
- contractual urgency of delivery;
- reliability of services (punctuality, safety and security);
- flexible prices according to contract quality;
- additional services.

Changes in logistics have given rise to various business proposals. Practically all leading enterprises and

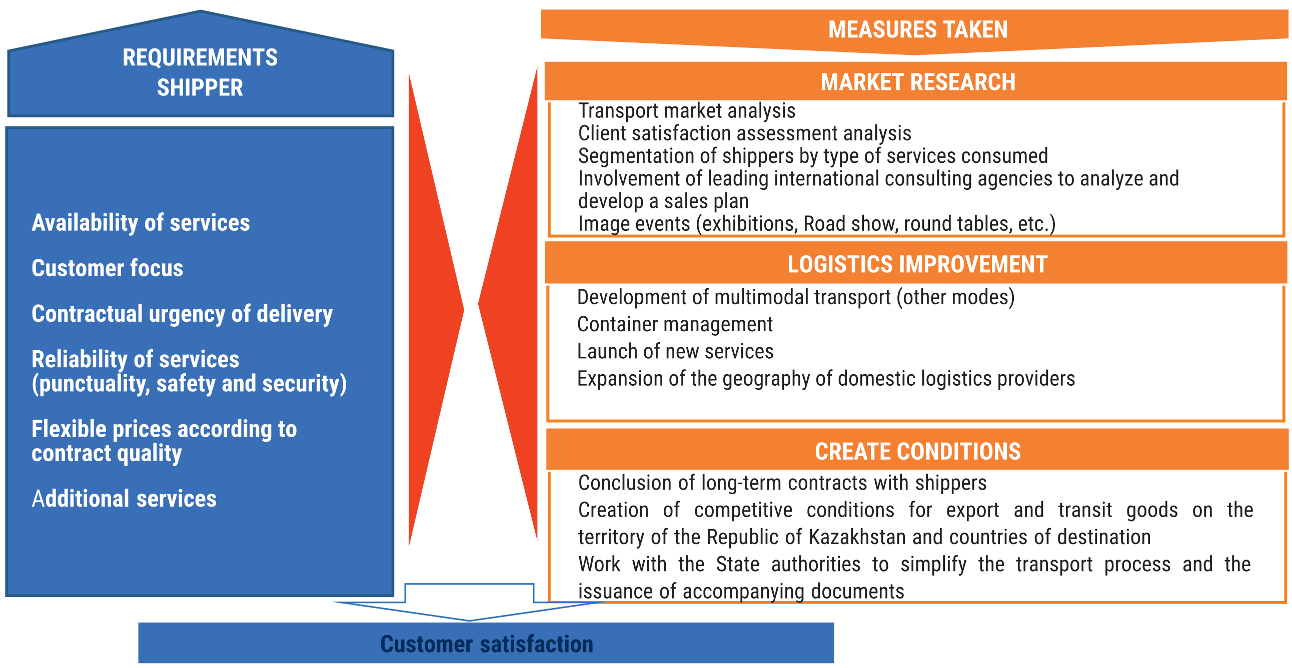

Fig. 3. Current expectations of shippers and measures taken

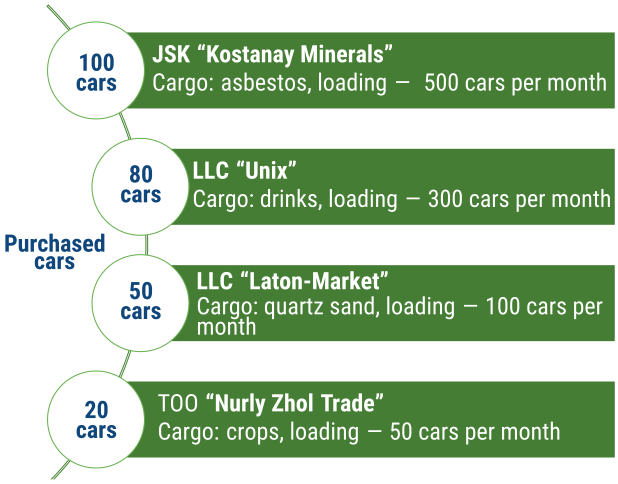

Fig. 4. Examples of realized cases

companies on the world RLU concentrate their resources on the main activities — this is the question of shippers. Each shipper strives to reduce the cost of goods and services, to ensure better quality, to increase competitiveness on the radar. And most importantly — in time to remove goods or raw materials.

In accordance with the current rules and requirements of RLU, complex logistics services are the most advantageous for customers.

Almost all of us faced with a shortage of cars, especially this is acutely felt during the "seasons" of mass loading. The main leitmotif of exporters become "wagons"!

And the expression "client is always right" is as relevant as ever!

A case was developed — the purchase of freight cars for private investment under long-term offtaker contracts for transportation with shippers.

As a result, all three parties get their benefits: investor — dividends, operator — wagons, shipper — timely export of goods.

Within the Association of Entrepreneurs "KIT" several cases were realized, which are presented in *Fig. 4*.

The implementation of these cases made it possible:

- to attract private investment for the purchase of own car fleet;
- offer exporters a service aimed at minimizing technological and transport costs;
- to apply a complex of transport and logistics services to Kazakh enterprises taking into account their specific features of production processes;
- increase the volume of cargo exports without additional costs;
- create new jobs of logistics competence;
- Increase tax revenue from freight transport.

At present, the Eurasian space has an extensive system of transport communication and is connected to all major MTC for access to the world radar (see *Fig. 5*).

FIVE MTCS HAVE BEEN ESTABLISHED AND ARE OPERATIONAL

This is the Northern Corridor (the route connects Western Europe with China, the Korean Peninsula and Japan. through which container trains pass through Kazakhstan in the direction of China – Europe.

The Central Asian corridor — provides transit transport between the Russian Federation and the countries of Central Asia (the route connects the countries of Central Asia with North – West Europe. From the side of Kazakhstan it is the section Saryagash – Arys – Kandyagash – Ozinki).

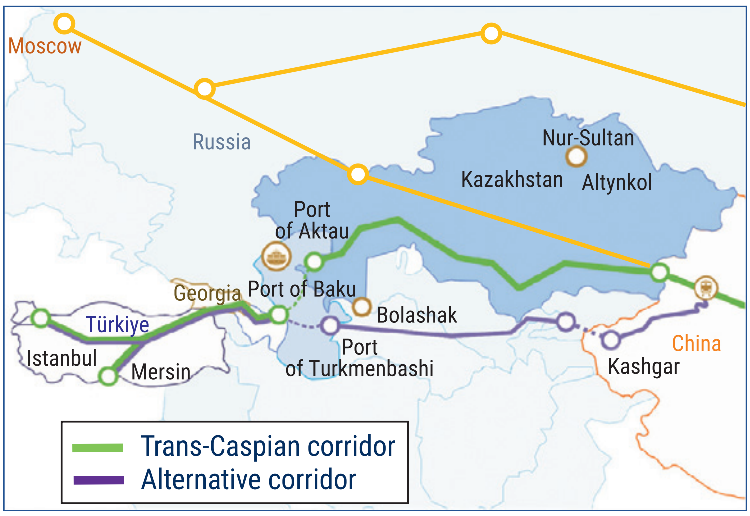

Fig. 5. Trans-Caspian and alternative transport corridors

South Corridor. This route connects China and the countries of South – East Asia with the countries of Central Asia and the Persian Gulf (the route connects the countries of China and the countries of South – East Asia through the countries of Central Asia, Iran, Turkey. Kazakhstan is the section Altynkol – Almaty – Shu – Arys – Saryagash).

North – South connects the Russian Federation with Iran, the Gulf countries, India. In addition, the Kazakhstan – Turkmenistan – Iran route (east North – South branch) currently connects China directly through us with Iran (route from Saint Petersburg to the port of Mumbai. From the Kazakhstan side — these are the sections Iletsk/Osinki – Beine/Ozen – Bolashak).

The TRACECA corridor, in which Kazakhstan is developing the Trans-Caspian International Transport Route (TMM) (the route connects Eastern Europe with Central Asia and China. From the side of Kazakhstan, this section is Altynkol/Dostyk – Aktau/Kuryk).

It is clear that, over the next 5 to 10 years, private investment will focus on:

- for the construction of terminals;
- for the purchase of rolling stock;
- the introduction of new technologies, further digitalization of the transport of goods and passengers;
- the development of transport and logistics business;
- for the construction of dry cargo and ferries.

For example, in order to further increase the transit potential of the Trans-Caspian route Kazakhstan plans to build a "container hub" in the port of Aktau.

The project will involve global logistics companies such as MAERSK, COSCO, PSA International.

In the port of Kuryk, the Novoshima grain company is building a grain terminal (capacity of 1 mln. tons, worth about 17 mln. dollars — private investment). Completion is planned for 2025.

"Semurg Invest" plans to build a multifunctional terminal (cost — 320 million dollars, private investments). Completion is planned for 2025.

Also, due to the shortage of ferry fleets in the Caspian Sea, Kazakhstan plans to build its own ferry boats in the amount of 10 units.

For reference:

Total merchant fleet — 153 ships.

Kazakhstan — 10 units, including on the Caspian Sea — 8 ships (including: 5 tankers, 2 dry cargo, 1 container ship), on the Black Sea 2 dry cargo.

Azerbaijan — 52 units (35 tankers, 17 ferries).

Iran — 35 units (dry cargo).

Russia — 46 units (5 tankers, 41 dry cargo).

Turkmenistan — 10 units (8 tankers, 2 ferries).

The share of Kazakhstan on the Caspian Sea is 39 %.

In addition, in order to upgrade the rolling stock until 2025, it is planned to buy semi-cars, platform cars, trunk locomotives.

Today, work is actively carried out on the modernization of transport infrastructure on the section "Dostyk – Moyinty", which is part of the transit corridor China – Europe;

- building bypass. Almaty line, which will unload the Almaty junction by 30 % and reduce the delivery time to 24 hours;
- construction of the new "Darbaz – Maktaral" line, which will give impetus to the development of the Central Asian corridor.

Work is underway to establish cooperation with the Singapore company "PSA Group", which offers to integrate their ready-made information systems into freight logistics.

For reference: The integration of information systems will serve as an additional impetus to the development of MTK, as the global PSA network covers more than 50 offices in 26 countries. The Group's portfolio includes more than 60 deep-sea, i.e. inland terminals.

Of course, it is worth noting that neighboring countries also have an investment policy aimed at the development of their transport infrastructure and logistics.

For example, China, Kyrgyzstan and Uzbekistan are considering the construction of an alternative route to the Caspian Sea, which will facilitate the development of transport in the direction of Turkmenistan, the countries of the Caucasus, Turkey and Iran. Alternative Corridor (cf. *Fig. 5*) is actively supported by the Administrations and State Bodies of Uzbekistan, Azerbaijan and Georgia.

Iran is firmly committed to restoring the Herat – Khaf section, which will connect Afghanistan and Iran. Iran is committed to the restoration of this section.

Completion of the construction will further develop trade links with Afghanistan's most successful city of Herat and create a corridor to the Middle East, as well as through the Iranian port of Chakhbehar to India, Europe and South-East Asia.

The business outlook for the next 10 years shows that the main trends for the next 10 years are:

1) logistics will become fully electronic (business environment), the emphasis will be on the environmental friendliness of transport;

2) technology and innovation imports will quadruple;

3) exports of goods will double, 40 % of the exports will be finished products;

4) the growth of human capital and the need for educational purposes in logistics;

5) monetization of research and development in logistics;

6) the inflow of foreign capital will quadruple;

7) trade in food products will increase by a factor of 1.5 to 2, which is related to the organization of food security of Asian countries.

CONCLUSION

At present, the key task of railway transport is to maintain current customers thanks to the reliability and speed of traffic. The main direction, as throughout 2022, remains the development of new points of activity and diversification of complexes of logistics services, which will allow to offset the effects of reduced segments of activity, using developments published in sources [1–7].

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The authors declare no confl icts of interests.

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The article was submitted 25.10.2022; approved after reviewing 15.01.2023; accepted for publication 30.02.2023.

Original article
UDC 656:658.7:339.138
doi:10.46684/2023.1.9

Co-marketing and Cooperation of the Transport and Logistics Complex in a Challenging Economic Environment

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ABSTRACT The article deals with the issues of cooperation in the context of increasing sanctions imposed on the Russian Federation transport and logistics complex (TLC).

A comprehensive express analysis of the impact of sanctions in different aspects of cooperation has been carried out. The system of anti-crisis measures to reduce the damage from the sanctions imposed on the enterprises of the Russian TLC has been studied.

The factors of co-marketing and cooperation in the TLC have been researched as well. The content of the cooperation concept in the TLC has been outlined and the possibility of a targeted and territorial approach stipulated.

A sequence of steps for measuring business processes performance and dynamic models of economic development have been worked out. The cooperation framework of TLC enterprises has also been presented. Besides, in order to solve the problems of co-marketing, an algorithm of business process optimization of business entities with respect to different social groups of consumers has been proposed.

In the deteriorating economic environment, it is necessary to regulate the system of cooperation in order to increase the TLC customer loyalty. It has been proposed to frame the interaction of TLC business entities on the principle of co-marketing, and to focus on the issue of regional residential community development, both by businesses and by the State.

KEYWORDS: co-marketing; transport and logistics complex; cooperation; targeted approach; territorial approach; sanctions pressure; parallel imports

For citation: Ksenofontova T.Yu., Gulyaeva O.A. Co-marketing and Cooperation of the Transport and Logistics Complex in a Challenging Economic Environment. *BRICS transport*. 2023;2(1):9. https://doi.org/10.46684/2023.1.9.

Научная статья

Ко-маркетинг и кооперация транспортно-логистического комплекса в сложных экономических условиях

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АННОТАЦИЯ Рассмотрена проблематика кооперации в условиях возрастающего санкционного давления на транспортно-логистический комплекс (ТЛК).

Проведен комплексный экспресс-анализ воздействия введения санкций по направлениям кооперации. Изучена система антикризисных мер по снижению ущерба от влияния санкций на предприятия российского ТЛК.

В равной степени исследованы факторы ко-маркетинга и кооперации в ТЛК. Раскрыто наполнение концепции кооперации в ТЛК; оговаривается возможность применения целевого и территориального подходов.

Определена последовательность оценки эффективности бизнес-процессов, динамические модели развития экономики. Представлена схема системы кооперации организаций ТЛК; кроме того, для решения задач ко-маркетинга предложен алгоритм оптимизации бизнес-процессов субъекта предпринимательства по критерию различных социальных групп потребителей.

В условиях ухудшения экономической ситуации для повышения лояльности потребителей ТЛК необходимо наладить регулирование системы кооперации. Предложено построить взаимодействие субъектов предпринимательской деятельности ТЛК на основе принципов ко-маркетинга, уделить внимание проблеме развития населенных пунктов регионов, как предпринимателей, так и государства.

КЛЮЧЕВЫЕ СЛОВА: ко-маркетинг; транспортно-логистический комплекс; кооперация; целевой подход; территориальный подход; санкционное давление; параллельный импорт

Для цитирования: *Ксенофонтова Т.Ю., Гуляева О.А.* Ко-маркетинг и кооперация транспортно-логистического комплекса в сложных экономических условиях // Транспорт БРИКС. 2023. Т. 2. Вып. 1. Ст. 9. https://doi.org/10.46684/2023.1.9.

INTRODUCTION

Technological, socio-economic and environmental changes in recent decades have led to a rethinking of approaches to management of the transport and logistics complex development (TLC). In addition to the external factors, Russian TLC enterprises have been affected by successive economic sanctions since 2014. These sanctions have resulted in the restriction of TLC operations and deliveries of imported products not produced in our country, as well as sophisticated equipment, technologies and dual-use goods to Russia.

On 25 February 2022, the European Commission published a regulation restricting exports of certain product groups from the European Union to the Russian Federation. European suppliers must obtain special licenses to export goods to the Russian Federation. From 3 March 2022, US companies must also obtain licenses to export certain types of equipment and electronics to Russia. The authorities in charge of issuing such licenses have been encouraged to make active use of the “denial policy”. Australia, South Korea, Canada, Japan and several other countries have joined in restricting the shipments to Russia.

In the current circumstances, Russian enterprises engaged in production and economic activities in the TLC sector have been advised to implement a strategy of cooperation and joint marketing (co-marketing) as an anti-crisis toolkit.

MATERIALS AND METHODS

The governments of the sanctioning countries do not oblige international TLC companies to withdraw from the Russian market. However, many foreign transport companies are forced to suspend or terminate their operations in the Russian Federation. The transport and logistics corporations have been acting under strong pressure when making their own decisions about continuing/terminating their operations in Russia in the current international political context.

Sanctions are indirectly affecting the structure of all Russian foreign economic activity. One of the effective crisis response tools for Russian TLC enterprises can be collaboration in management of multimodal and international cargo transportation as well as joint marketing (co-marketing) [1–3].

Cooperation and co-marketing enable businesses to remain in the market and continue their business activities in the face of economic sanctions and restrictions. *Fig. 1* and *2* show the total number of sanctions against a number of countries worldwide and the sanctions’ impact on various sectors of cooperation in Russia.

To support the importing companies, the Government of the Russian Federation and the Ministry of Industry and Trade have taken a number of actions. A simplified customs clearance of imported goods has been introduced, customs certification for certain categories of goods have been revoked, and parallel imports have been allowed. The exemptions should facilitate an uninterrupted supply of production components. The measures taken will also help to avoid shortages on the consumer market and in the TLC sector.

Currently, import certification is allowed based on the documentation provided by the companies import-

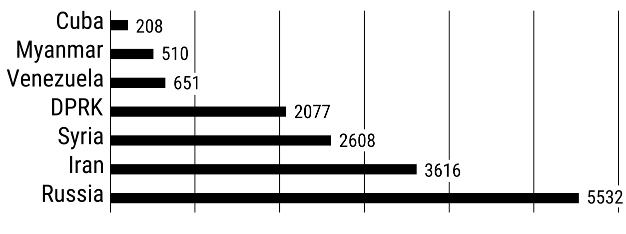

Fig. 1. Distribution of the sanctions imposed worldwide

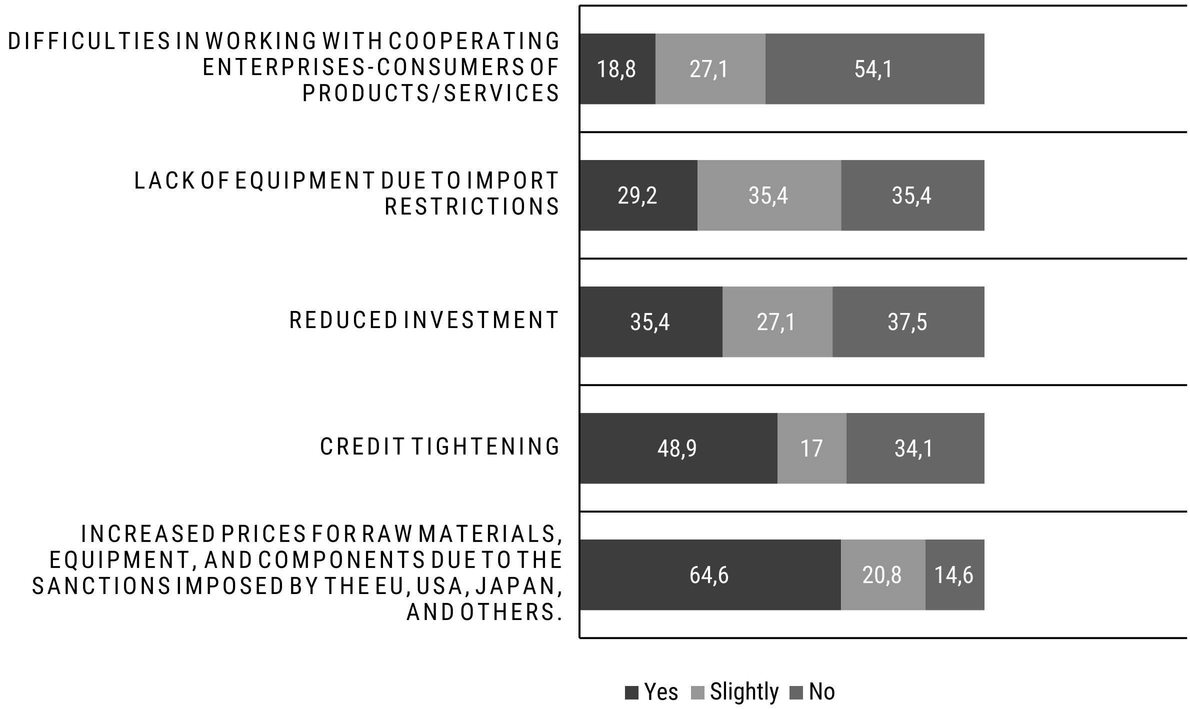

Fig. 2. The aspects of cooperation affected by the sanctions and their assessment

ing products and the importers may conduct compliance assessment without the involvement of accredited laboratories. Importers have an option of confirming product compliance with the technical regulations and national standards based on their own documentation provided. Customs clearance of goods made under the simplified scheme must be registered with the Federal Accreditation Service (Rosakkreditatsiya). Order No. 3898 of the Ministry of Industry and Trade issued on 14.09.2022 contains a list of exceptions. From January 2022, the Eurasian Economic Commission Council Decision No. 130 cancelled the certification of certain types of imported products.

The adopted regulations apply to equipment and spare parts (components), so the manufacturing companies will benefit from the changes in regulations. Customs certificate and bill of entry will not be required when importing:

- spare parts for service and repair of machinery that was imported or manufactured in Russia earlier. The importer must be an official brand representative;
- spare parts to be used in the manufacture of products for the importer's own needs;
- used equipment and machinery.

Until 2022, the Russian Federation had a national system of exhaustion of rights. Manufacturers supplied goods only through a network of authorized distributors. By Order No. 1532 of 19.04.2022, the Ministry of Industry and Trade of the Russian Federation established a list of products permitted for import under the new regulations.

Parallel imports are subject to international legislation and are not considered smuggled or counterfeit goods. They are subject to all applicable certification requirements. For goods certification in 2023 it is required:

- to define the technical regulations and import licenses applicable to the goods;
- apply a simplified customs clearance system according to the exemption list of the Ministry of Industry and Trade;
- create the possibilities for parallel imports of branded products in accordance with the order of the Ministry of Industry and Trade or with the help of certification centres.

All this suggests that the Russian government have actively participated in reducing the burden of the economic sanctions and restrictions on the enterprises of the Russian TLC. In combination with the measures of the government support, cooperation and co-marketing in the aspect of logistics make the implemented business processes more efficient [2–7].

RESULTS

The success of cooperation lies in co-financing of the business needs of TLC member companies such as forwarding and warehouse operators, distribution

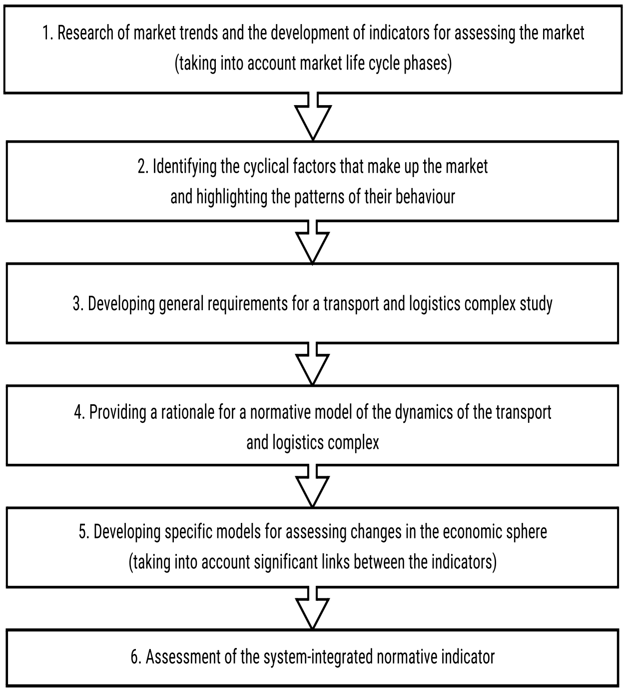

Fig. 3. Algorithm of the methodology for assessing business activity in the economic environment

companies, as well as companies involved in shaping the transport and logistics services market (raw material and commodity suppliers, consulting and IT companies, etc.).

Government funding for various aspects of digitalization and innovative development of TLCs also contributes to successful cooperation. State development programmes have defined the State commitment in promoting the digitalization of the country's TLC economy [3–6].

The legislation regulating the development of the digital economy in Russia is in line with similar foreign documents in terms of the time of adoption and content. Nevertheless, as practice shows, the Russian TLC has experienced a need for co-operation, new technological solutions, digitization and digitized platforms. The evaluation method of socio-economic efficiency of business activities in the framework of transport and logistics company cooperation is presented in *Fig. 3* [4].

The best tool to improve the socio-economic efficiency of business cooperation lies in the multi-criteria optimization method. With this method, the structure of the incoming cash flows will be optimal if the businesses activities grow, the businesses income growing too. Optimizing the structure of incoming cash flows is essentially a question of allocating shares of business income, payroll fund and dividends to the maximum satisfaction of all parties. Two levels of regulation — internal and external — need to be distinguished.

The relationship between predictive analysis ("potential assessment") and retrospective analysis (analysis of dynamics) has been used for developing a method for analyzing the dynamic potential of the cooperation participants in the sphere of transport and logistics services [2–5]. The procedure of the dynamic potential analysis of the participants is presented in *Fig. 4*.

This kind of analysis can be carried out based on different dynamic system models:

— a model of the relationship between the growth rates of wealth accumulation and consumption and of gross domestic product;

— a model of the business bankruptcy dynamics;

— a model of investment development;

— a model of innovation development.

The "Golden Rule" in economics is applied to the algorithm (*Fig. 4*). This modification is developed by adding a social performance indicator to the basic model. This indicator illustrates the particular activities of cooperation participants in the framework of individual missions of enterprises working in the field of transport and logistics services [5, 6].

The Russian practices of TLC co-marketing including the development of digital technologies should be focused on improving the competitiveness of Russian transport companies and agglomerations as well as creating an effective system of regional management and safe and comfortable living conditions for residents.

TLC cooperation can be established in various formats, for example, consortiums and consumer co-

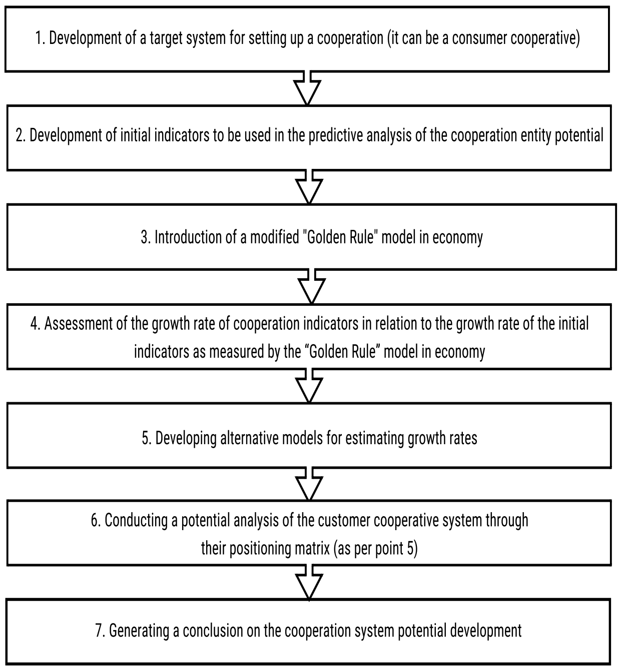

Fig. 4. Sequence of steps for the dynamic potential analysis of a cooperation system participants

operatives. The cooperation system of TLC enterprises is shown in *Fig. 5*.

The cooperation as a non-profit institution promotes the economic and social development of the region [7].

In order to implement the cooperation model (*Fig. 5*), the TLC sector participants need to develop business and production activities through team cooperation in order to improve the social and economic situation in the regional units of the Russian Federation [8]. Such activities include:

1) identifying social groups;

2) mapping the sources of incoming cash flows of social groups;

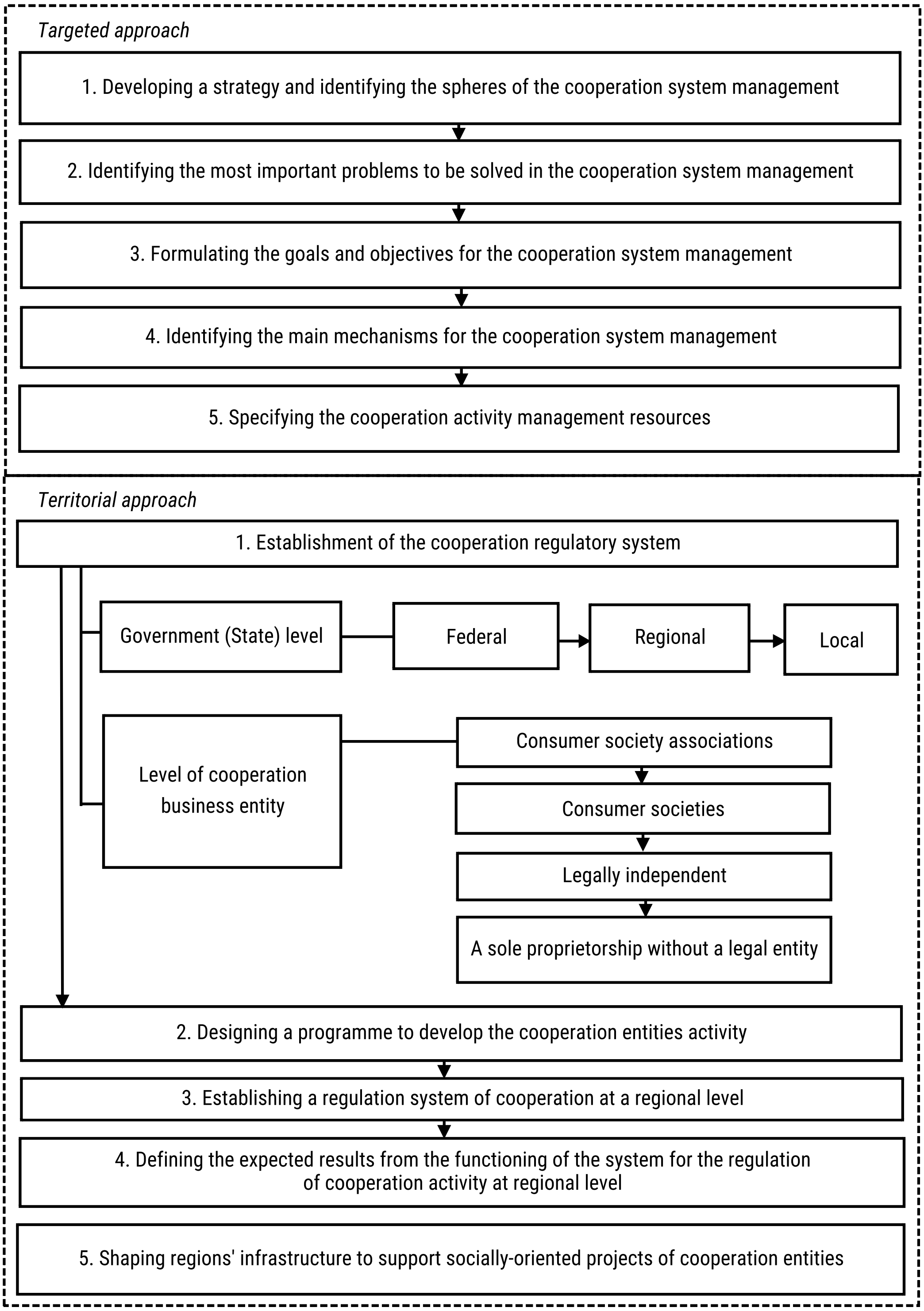

Fig. 5. The cooperation system of transport and logistics companies

3) choosing and substantiating the income calculation method;

4) optimising the structure of incoming cash flows;

5) developing the guidelines for the harmonization of the interests of social groups.

CONCLUSION

In order to support the enterprises carrying out production and business activities in the sector of transport and logistics services, it is necessary to establish an effective interaction of the TLC entities based on the principles of co-operation and co-marketing. Both business entities and the State should pay serious attention to this issue.

As mentioned above, cooperation will ultimately allow for an effective co-marketing (joint marketing) strategy implementation, which will reduce the outflow of people from the economically deteriorating regions, provide for the support of the domestic market, reduce the advertising costs for each company, and increase the loyalty of TLC customers.

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Contribution of the authors: the authors contributed equally to this article.
The authors declare no conflicts of interests.

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The article was submitted 25.01.2023; approved after reviewing 15.02.2023; accepted for publication 30.02.2023.