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Introduction of the Latest Railway Technology based on Intersectoral Cooperation

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ABSTRACT

The article studies direct and external effects produced by the development of railway infrastructure facilities. Examples of intersectoral cooperation in the transport sector in Russian and international practices confirm that development of intersectoral production and transport interaction of business entities allows to radically accelerate scientific and technological progress in the railway industry, namely, to develop and introduce new models of railway rolling stock, new transportation technology, considering also regional features of the transportation market.

The practical part considers the advantages of introduction of freight electric multiple-unit trains (FEMUT), identifying the main groups of cargo owners, for whom this type of rolling stock is intended. The results of calculations show possible reduction in running time and in specific consumption of electric power when introducing FEMUT. The calculated costs of self-propelled (motor) and trailer wagons of FEMUT are followed by the results of economic calculations of NPV of life cycle operation of FEMUT in comparison with a train with locomotive traction. To achieve the stated objectives of the research, the work uses methods and tools of technical comparison and of financial planning.

Keywords: *railway transport, transport and industry partnership, multiple-unit freight trains, distributed traction, accelerated freight transportation, energy efficiency.*

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Introduction.

From a macroeconomic point of view, railways can be considered as both an index and instrument of macroeconomic policy. The progress in other sectors of the economy, transport mobility of the population, and comprehensive development of territories depend on the activity of railways. The delays in rate of development of transport infrastructure, lagging in introduction of new technology and rolling stock, and that is particularly important for Russia, are unacceptable being the factors constraining a country's economic growth.

The *objective* of the research described in the article is to substantiate the economic efficiency of introduction of modular freight trains for certain types of transportation (container, piggyback transportation, carriage of refrigerated goods), to determine the range of goods for which this type of rolling stock is most effective.

To achieve this objective, the research applied *methods* of comparative analysis, content analysis of technical information, planning of cash flows and financial calculations.

Social and economic efficiency of innovations

In Russian Federation, according to the Program of Structural Reform in Railway Transport, the objectives of the reform are: to increase stability of operation of railway transport, its accessibility, safety, and quality of services provided by it to ensure a single economic space of the country and national economic development; to form a single harmonious transport system of the country; to reduce total national economic costs of railway transportation; to meet the demand for railway services [1].

Omitting past discussions happened about problems and consequences resulting from the reform (it is possible to mention [2] as one of noticeable but most controversially estimated works dedicated to that topic) it is worth highlighting that emergence of new transport arteries, improvement of transportation technology on existing railways generate not only direct benefits obtained directly by the owner of the transport infrastructure, but also external, complex multiplier effects.

Direct transport effects include:

• additional income from collection of fares and transportation of goods by rail;

• reduction of cost of transporting goods and passengers with other modes of transport due to improved road conditions (reduced traffic jams, decreased rate of road accidents, increased delivery speed compared to water transport, reduced delivery costs compared to air transport);

• reduction of capital investments in other objects of transport infrastructure due to a decrease in time of delivery of goods and passengers;

• reduction of transport losses associated with compensation for damage environmental damage (the effect of reducing CO_2 emissions from road and air transport, pollution of water infrastructure.

External effects are associated with receipt of benefits by economic entities in the non-transport industry. These effects include:

• reduction of losses of passenger travel time, including due to reduction of traffic congestion;

• reduction of unproductive losses of passengers by reducing transport fatigue (decrease in labor productivity after a trip);

• reducing the need of enterprises and organizations in current assets due to increase in speed of delivery of materials and finished products because of improvement of equipment and technology of transportation;

• reduction of losses from road accidents;

• increase in the value of real estate, as well as of rental rates for real estate because of development of the adjacent transport infrastructure;

• increase in property and land tax revenues from real estate, thanks to development of the adjacent transport infrastructure;

• increase in income taxes on profit and value added from operation and sale of real estate, caused by development of railway transport;

• effect of growth of incomes of the population following creation of new jobs and, as a consequence, the growth of tax revenues on the income of individuals in the non-transport sectors;

• effect of growth in the net profit of economic entities associated with an increase in purchasing activity due to creation of new businesses and jobs in the region adjacent to the transport artery;

• effect of an increase in accessibility of territories and, as a consequence, of development of tourism;

• effect of reducing the crime rate due to increased employment of the population following creation of new jobs in the areas adjacent to the transport infrastructure.

The evaluation of the public (socio-economic) efficiency of implementation of measures focused on development of transport infrastructure should be made by comparing public costs and results, which will take place in transport sector (direct effects) and in non-transport sectors of the national economy (external effects) in case of implementation of these measures with the costs and results, which will take place in case of failure of their implementation.

Intermodal and intersectoral cooperation

All above external out-of-transport effects can be measured in monetary terms and their impact on the country's total GDP can be assessed. Of course, the state is the main stakeholder and beneficiary of investments in construction, modernization, and maintenance of transport facilities. However, to obtain direct transport effects under the conditions of saturation of the transport services market, modern methods and forms of management should be applied by non-state business entities. As an example of this approach, we can cite the project for development of the tourist cluster «Sortavala–Ruskeala–Valaam» in the vicinity of low loaded West Karelian railway. In December 2018, the High-Speed Transportation Directorate of JSC Russian Railways (DOSS) launched two pairs of high-speed trains «Lastochka» on the route St. Petersburg–Sortavala, which, in addition to serving tourists in the cluster, also take over part of the socially important transportation between small settlements of the Republic of Karelia and Leningrad region. At the same time, the level of transport services in the region has improved. If earlier it was necessary to travel by bus from St. Petersburg to Sortavala along a winding road for 6–7 hours, now Lastochka electric train covers this distance in just four hours. It is possible to see the tourist sites of Sortavala, Valaam Monastery or Ruskeala Mountain Park during a single day. With insignificant profitability or even unprofitableness, and the need to operate two types of traction on this route (diesel and electric locomotives), the project obtained an integral socio-economic effect, which should be redistributed between the subjects of the tourism sector and the transport business. Such redistribution can take the form of creation of joint ventures (for example, transport and tourist enterprises), contracts for transportation, concession agreements, etc.

International practices show examples of transport projects of intermodal and intersectoral cooperation comprising: passenger intermodal railway and bus transportation of the Czech companies Leo Express and RegioJet with their own locomotive, car and motor-car fleet; freight transportation of contrailers by Mercitalia electric multiple-unit trains in Italy; intermodal rail, bus and ferry services of the Japanese company West Japan Railway; diversified business of the railway company Union Pacific Railroad Co in the USA, including transportation of agricultural products, cars, chemicals, coal [3]. The rolling stock of these multi-industry holding companies was purchased and designed directly for the needs of the company's production units and specific customers of transportation services.

The creation of transport and production associations, participation in railway transport business of organizations and industries that are vitally interested in stable operation of transport, ensuring a well-coordinated transportation schedule for their own needs allow to ensure introduction of advanced, science-intensive railway technics, equipment and technologies at an accelerated pace.

Freight electric multiple-unit trains as the object of cooperation

Scientific research concerned traction and energy calculations, and also an algorithm for composition of modular Freight Electric Multiple-Unit Trains (FEMUT) by the criterion of energy efficiency [4–8].

In author's opinion, the introduction of this rolling stock will be of interest to those participants in the transportation market who need to increase the rhythm of shipments, safety of cargo along the route, to reduce the risk of goods being defrosted during transportation in refrigerated containers, and to save energy for traction of trains.

The use of FEMUT makes it possible to reduce the longitudinal compressive loads on wagon couplers up to 400 kN (by 6,25 times compared to locomotive-hauled wagons), to lighten weight of metal structures of wagon frames by 1,6 tons (by 7,3 % of the total container weight). At the same time, the decrease in the cost of FEMUT trailer car will amount to RUB76,8 thousand or 3,84 %. Saving the weight of wagon container allows, with constant tractive power and the number of motor wagons, to increase the number of trailer cars within FEMUT. Considering the additional mass of cargo, the tare coefficient of

FEMUT will become less than that of a locomotive-hauled train.

Since there will be a possibility of using electro-pneumatic brakes (EPB) for FEMUT and reduced response time for braking, it will be possible to reduce the stopping distance of the train by 30–40 % and thereby to increase speed of movement – to process freight trains according to the passenger's schedule or in the in the same schedule slot with passenger trains, which will unload transit capacity of railway lines. In addition, the use of EPB for FEMUT will reduce time for testing the brakes at stations, improve controllability and safety of the train, since the driver, using an electro-pneumatic line, will constantly be able to control pressure in brake cylinders and charging tanks of each wagon. In a freight electric train, it is possible to implement the concept of reducing the charging pressure in the brake line and increasing the density of connection of brake networks, which will help not only to reduce the energy costs of driving the train and increase the service life of compressors, but also, most importantly, to improve controllability of train brakes, which plays the most important role in ensuring traffic safety [9].

The operating costs for transit of train flows will decrease, since the rate of strong braking and subsequent acceleration of freight trains will significantly decrease, which means reduced consumption of electricity for traction. It was revealed that the power consumption when regulating the total power of traction electric motors in FEMUT is lower than that of a locomotive-hauled train, since in FEMUT the regulation of the required power is more maneuverable due to the lower power of each individual traction motor and a larger number of them. The greatest effect when using the algorithm for turning off excess power at FEMUT is manifested in sections with a variable flat-mountain track profile, which allows to significantly save energy for traction of trains when using FEMUT on latitudinal network segments. Calculations made at Medvezhya Gora–Novy Poselok section of Oktyabrskaya railway, showed decrease in specific power consumption in the direction «there» by 4,6 %, and in the direction «back» by 3,9 %, compared to a train of similar weight driven by an electric locomotive 3ES5K. On Krivenkovskaya–Goyth section of the North Caucasian Railway, the specific power consumption in the direction «there» is 4,6 % less, in the direction «back» it is less by 0,4 % in comparison with the train of the same weight driven by 3ES4K electric locomotive. The travel time with FEMUT on Krivenkovskaya–Goyth section in the direction «there» is less by 2,6 %, in the direction «back» it is less by 9,3 %.

The problems of energy efficiency management in multi-engine traction modules are constantly followed by researchers since their solution includes significant reserves for reducing the cost of transportation [10–13].

The use of electrodynamic brakes is also more efficient and safer at FEMUT compared to a locomotive-hauled train, since braking is performed by motor cars distributed along the train, which reduces the risk of derailing of trailer cars, squeezing them out in curves, and also reduces the longitudinal-dynamic reactions of the train at breaking track profiles.

We have determined the target (currently maximum allowable) prices of a FEMUT motor (self-propelled) wagon which is 60 million rubles, of a FEMUT trailer car (1,92 million rubles), and one-time costs for the depot equipment for operation FEMUT (equal to 20 % of the purchase price of FEMUT). With such parameters of capital investments for introduction of this type of rolling stock, in terms of total technological, economic effects by the criterion of the maximum net present value (NPV) for the period of operation, operation of FEMUT is preferable as compared to trains with locomotive traction. For example, when comparing two trains, a FEMUT and a locomotive-hauled train with an electric locomotive 3ES5K, both capable of carrying a load of equal weight (4000 tons) with an equal traction power of 9600 kW and equal profitability rates, for a period of operation of 40 years, the NPV value for a train with an electric locomotive 3ES5K will be 21,039 billion rubles, for FEMUT it will be 21,101 billion rubles, i.e. 0,3 % higher, which confirms the competitiveness of FEMUT with the given characteristics.

The composition of multi-unit freight trains must undoubtedly be variable. At the same time, it is possible to use an automatic digital coupler, the use of which will allow not only to couple/uncouple the wagons quickly and automatically, but also to auto-connect the air ducts of brake lines, electrical contacts of power lines of various circuits (EPT, refrigerators, etc.). The use of freight electric trains solves the problem of stable and reliable power supply of refrigerated containers, specialized demountable bodies of tank cars that require energy to ensure operation of steam jackets, thermal electric heaters and coolers that ensure transportation of bulk cargo in proper condition over long distances. The use of electric freight trains is also possible for accelerated contrailer transportation, which will reduce specific CO_2 emissions and have a positive environmental effect. Biggest capacity for organizing piggyback transportation in Russia, in our opinion, belongs to the most loaded road transport routes, where a higher speed of passage of border crossings and delivery of goods by rail will be a factor for a significant reduction in logistics costs. These areas include Moscow–St. Petersburg–Finland, Moscow–Minsk– Brest–Warsaw, Moscow–Minsk–Vilnius–Kaliningrad.

Conclusions. The creation of modular freight electric multiple-unit trains within the framework of transport and production cooperation is possible for such industries as production and transportation of food products, technical liquids requiring special temperature conditions during storage and transportation, accelerated delivery of high-tech household and computer equipment, machinery and equipment, medicines, fashion items, other goods with high added value. Besides, the advantages of freight electric trains will manifest themselves at railway network segments with unstable freight traffic, on sections with a complex track profile, where forced stops and accelerations on steep ascents and descents are possible, where pushing and double traction are used.

Freight electric trains represent specialized rolling stock, and its implementation will not in the least cancel further development of locomotive-hauled trains, the main scope of which will still comprise transportation of bulk, raw materials. The need of the modern economy, compliance with the goals of reforming railway transport, the emergence of the institution of private specialized carriers will allow FEMUT to occupy a significant position on domestic, international and transit routes.

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