Big Data Processing of Commodity Flows in the Transport and Economic Balance of the Russian Federation

Oleg Evseev[1[0000-0002-2437-6497]], Vasily Murashov[1[0000-0002-3633-7495]],

Alexander Zaboev[1[0000-0001-9295-1708]], Anton Zemtsov[1[0000-0003-1385-768X]],

Victor Buslov[1[0000-0003-0559-5931]], Alexander Shubin[1[0000-0001-9863-4658]],

Alexander Schirov[2[0000-0003-0806-9777]], Anton Shubin[3[0000-0001-5518-1177]],

Anton Urazov[3[0000-0001-6699-7534]], Elena Anikina[3[0000-0003-1820-8507]]

[1] Scientific Center for Complex Transport Problems of the Ministry of Transport of the Russian Federation, Myasnitskaya Str. 16, 101000 Moscow, Russia
[2] Institute for Economic Forecasting, Russian Academy of Science, Nakhimovsky Av. 47, 117418 Moscow, Russia
[3] LLC "Geogracom", Office 4297, Warsawskoye freeway 42, 115580 Moscow, Russia
evseev@mintrans.org,aza@mintrans.org,schir@ecfor.ru

Abstract. Planning and forecasting transportation using econometric and mathematical tools based on the spatial input-output tables and knowledge of transportation effects is an important task for improving transport and regional economics. The spatial input-output tables of Russia further called the transport and economic balance of the Russian Federation aggregate the actual and forecast volumes of freight traffic between the regions of the country by rail, road, inland water and maritime transport by types of commodities. The actual information on freight traffic covering the period from 2007 to 2017 bases on statistics for industrial production, domestic and external trade, construction, agriculture, energy, as well as transport statistics and takes into account the relationship between production and consumption, import and export of goods. The features of the Russian statistical accounting specify the order of Big-data processing while calculating the balance.

The transport and economic balance of the Russian Federation provides the forecast of interregional trade flows, transportation infrastructure loading, changes in transport network capacity, transportation costs and time. The forecast of cargo load and interregional freight flows covers the period up to 2030. The forecast model uses Russian economy growth scenarios of the Ministry of Economic Development of Russia, as well as regional economic development scenarios including changes in the technological and transport connectivity of main cargo generating industries.

Keywords: Big data, Traffic Flows, Forecasting, Transport, Transport Policy, Transport Statistics, Transport Connectivity and Economic Relations, Spatial Input-output Tables, Transport and Economic Balance, Transport Planning, Transport Models.

1 Introduction

Sustainable and efficient functioning of the transport system is an important focus of the economic policy of any country. It is the target of national strategies, plans and transport development programs, as other documents setting the main priorities of the state transport policy. These plans are based on forecasts of demand for transport services, production, consumption and shipping of main goods, prospects for development of international trade, investment, etc.

In the Russian Federation, and earlier in the Soviet Union, issues of transport development based on economic and mathematical models of planning and forecasting, as well as transport intersectoral balance accounting, were developed by the Institute of Complex Transport Problems of the USSR State Planning Committee (IKTP) [2], and Central Economics and Mathematics Institute of the Academy of Sciences of the USSR (CEMI) [6, 7].

The balance approach was implemented for transport and economic links planning not only in the USSR, but also in the member states of former Council for Mutual Economic Assistance (CMEA).

During the 20 years after USSR dismissed on the way to the transition to market economy, methods based on spatial input-output tables were no longer used in the transport work forecasting. The economic growth of the 21th century and the even more rapid growth of oil and gas, coal, steel, mineral fertilizers exports volume, caused the greater transport network loading and occurring of "bottlenecks". All of these required a revision of the approaches to transport policy and transport planning methods.

The transport strategy of the Russian Federation for the period up to 2030, approved by the decree of the Government of the Russian Federation of November 22, 2008 No. 1734-p, as amended by the Government of the Russian Federation of June 11, 2014 No. 1032-p, designated a balanced, advanced infrastructure development as the most important strategic target for the transport system development. Realization of this goal means coordinated integrated development of all elements of the transport infrastructure based on spatial (interregional) input-output tables.

That means to develop a statistical accounting system, mathematical methods of forecasting and modeling describing needs of economic and population sectors for transport services and the dynamics of the freight base [8].

Transport and economic balance (TEB) is a form of spatial input-output tables for planning and forecasting of transport connectivity and economic relations, expressing the ratio between the size of production and consumption of goods and the need for the volume of transport work for their import or export.

2 Research objectives

The research target is the creation of methodological approach, mathematical tools and TEB's design procedures based on the data of the official statistical observation of economics and transport sector in the Russian Federation. The incompleteness and inaccuracies of the source statistical data for building a model of demand for freight transport, as well as mismatch between groups of production output and cargos items on modes of transport were the challenges on the beginning phase of the research.

The practical objective was to build a balance, describing the transportation of goods between all Russian regions over the past 10 years, as well as to forecast transport flows for the medium and long term.

The TEB should provide:

- a strong correlation between the forecasts of the transportation volume and expected indicators of socio-economic development and trade;
- correlation with international strategies and forecasts for the development of regional and world trade, energy and commodity markets;
- the usability of econometrics tools for forecasting the volumes of transportation and their directions in relation to indicators of socio-economic development;
- the applicability of integrated approach for solution of development problems related to different modes of transport, allocation of freight flows over the network and the rational modal split.

2.1 Main Sources of Research

The development of various models of transport and economic balance has been carried out for a long time worldwide (USA, Europe) during the past 25 years. For example, the Bureau of Transportation Statistics USA (BTS) provided the Commodity Flow Survey (CFS) on a regular basis since 1993 [13]. CFS is based on sample surveys of enterprises and contains information on interstate transportation in the U.S. by type of commodities. The main purpose of CFS is to give the government and business owners an overview of the commodity flows in the United States. On the CFS basis, the U.S. freight turnover is calculated, forecasted and monitored on regular basis under Freight Analysis Framework (FAF).

Similar activity implemented in Europe is provided by the European Commission, for example, in framework of the ETIS - BASE project (European Transport Policy Information System) [14]. The ETIS objectives are the development of metrology of consolidation and verification of national transport statistics data of the EU member-states and analytical support for decision-making process in transport planning in the EU.

Another appropriate study was conducted in the framework of the SUST-RUS Project with the participation of experts from the Russian economic school [26]. The study aims to identification of transport and economic links between the Russian federal districts. It establishes a convenient notation system which was implemented in the TEB framework for describing the basic equations of the interregional transport

and economic balance of the Russian Federation. The development of balance methods for modeling transport demand across the country is provided also in the studies of Dutch researchers [11, 12], where an efficient mathematical apparatus for transport and economic balance was developed. These scientific works have had a significant impact on the setting and pursuing objectives of the TEB study.

3 The Structure of the Transport and Economic Balance of the Russian Federation

The TEB describes the actual and forecast origin-destination freight flows between various regions of the Russian Federation by rail, road, inland waterway and maritime transport by types of commodities.

The TEB structure is set by a multidimensional OD-matrix of interregional freight flows, where the rows and columns correspond to the regions of origin and destination, and at the intersection of the rows and columns there are the volumes of freight flows by modes of transport and types of commodities (Fig. 1). Another dimension of the matrix is time that shows the historical volumes and the origin-destination information of cargo traffic from 2007 to 2017. A similar TEB matrix is being built for the forecast period 2019-2030.

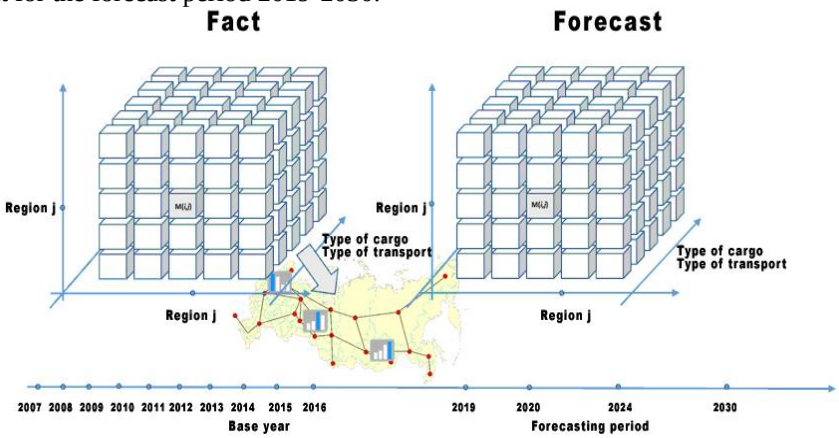

Fig. 1. Multidimensional matrixes of volumes and correspondence of freight traffic between regions by type of cargo and by modes of transport - a actual data and forecast for the period up to 2030.

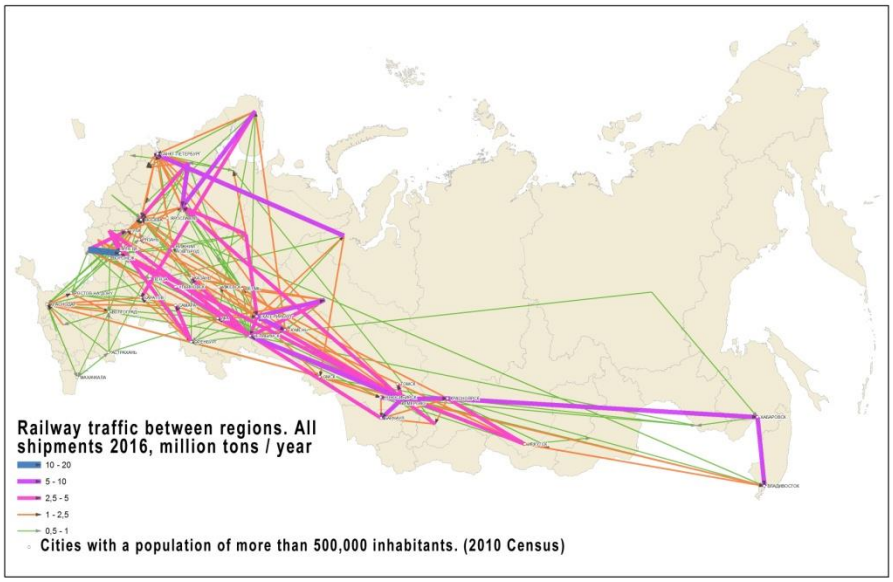

Fig. 2. Freight traffic between regions by rail. All shipments, 2016.

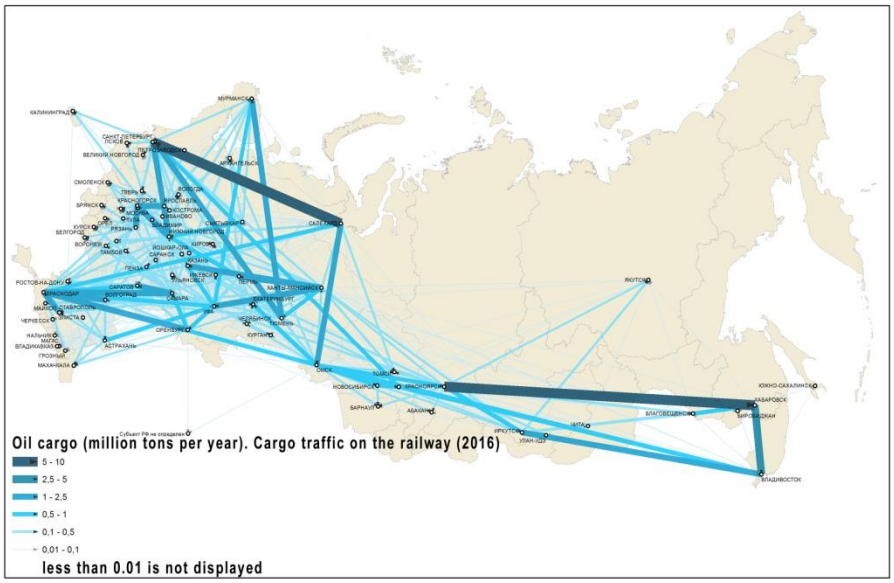

Fig. 3. Oil cargoes traffic by rail, 2016.

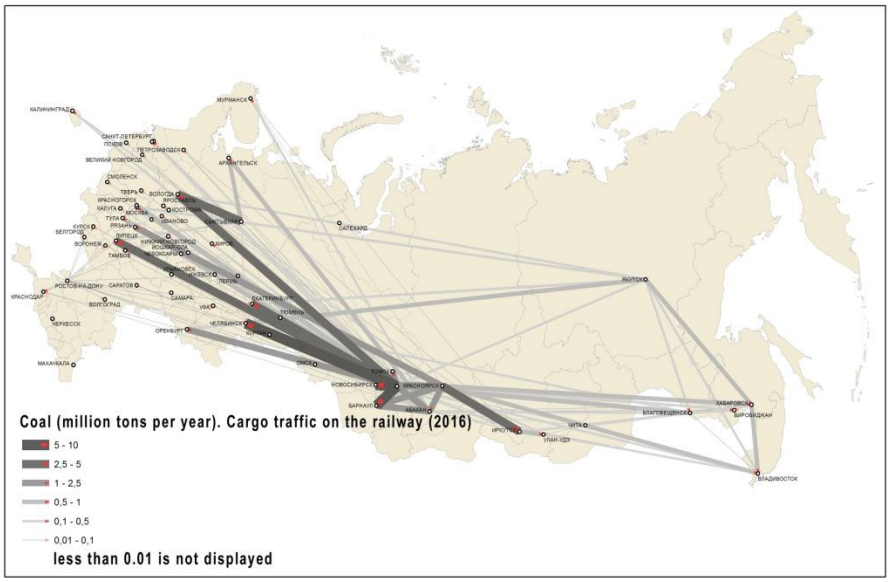

Fig. 4. Coal traffic by rail, 2016.

Fig. 5. Grain cargoes and their density, 2016.

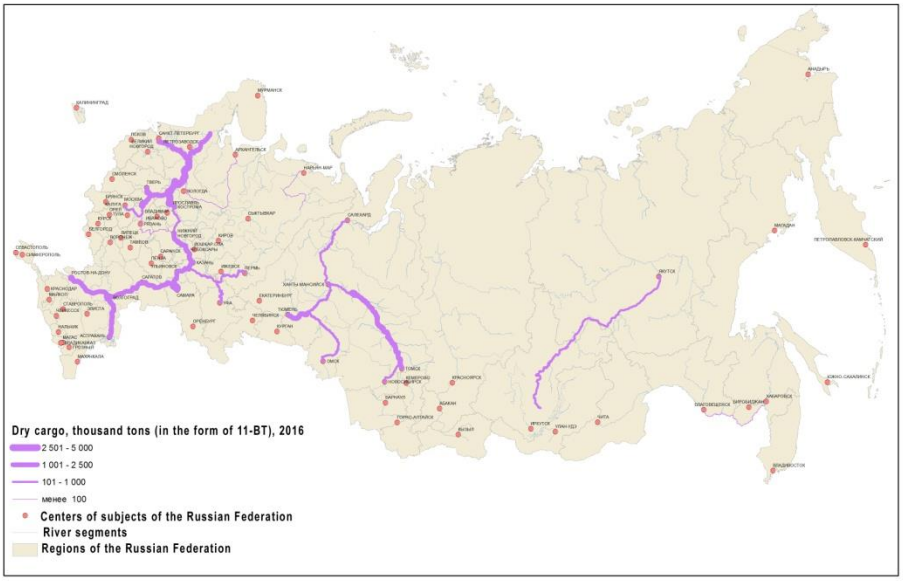

Fig. 6. Dry cargoes by inland water transport, 2016.

Fig. 7. Total cargoes by inland water transport, 2016.

The TEB matrices should satisfy the balance equations connecting the transport operations between regions and with the rest of the world across the border of the Russian Federation. The balance equations substantively reflect the balance of exports, imports, production, consumption, trade, import / export of goods between all regions, as well as the transport inside the regions.

The basic balance equations of TEB include the following relations:

$$XO_{i,r} = TR_{i,r} + EX_{i,r}\,, \quad (1)$$

$$EX_{i,r} = \sum_{rr}\sum_{k} EX_{i,k,r,rr}\,, \quad (2)$$

$$IM^{*}_{i,r} = \sum_{rr}\sum_{k} IM_{i,k,r,rr}\,, \quad (3)$$

$$TR_{i,r} = \sum_{rr}\sum_{k} TR_{i,k,r,rr}\,, \quad (4)$$

$$TEB_{i,r,rr} = \sum_{k} TR_{i,k,r,rr} + \sum_{k} EX_{i,k,r,rr} + EX^{MAR}_{i,r,rr} + EX^{IWW}_{i,r,rr} + IM^{MAR}_{i,r,rr} + M^{IWW}_{i,r,rr} + TR^{RAIL}_{i,r,rr}\,, \quad (5)$$

$$EX^{MAR}_{i,r,rr} = EX^{RAIL\to MAR}_{i,r,rr} + EX^{TRUCK\to MAR}_{i,r,rr} + EX^{IWW\to MAR}_{i,r,rr}\,, \quad (6)$$

$$EX^{IWW}_{i,r,rr} = EX^{RAIL\to IWW}_{i,r,rr} + EX^{TRUCK\to IWW}_{i,r,rr}\,, \quad (7)$$

$$IM^{MAR}_{i,r,rr} = IM^{MAR\to RAIL}_{i,r,rr} + IM^{MAR\to TRUCK}_{i,r,rr} + IM^{MAR\to IWW}_{i,r,rr}\,, \quad (8)$$

$$IM^{IWW}_{i,r,rr} = IM^{IWW\to RAIL}_{i,r,rr} + IM^{IWW\to TRUCK}_{i,r,rr}\,. \quad (9)$$

where:

$XO_{i,r}$ – shipment of goods (cargo) i in region r;

$TR_{i,r}$ – domestic transportation of goods (cargo) i from region r;

$EX_{i,r}$ – export of goods (cargo) i from region r;

$EX_{i,k,r,rr}$ – matrix of export transportation of goods (cargo) i from region r through the border of Russia, passing in the region rr, by mode of transport k;

$TR_{i,k,r,rr}$ – the matrix of domestic transport of goods by modes of transport, including intraregional transportation;

$IM^{*}_{i,r}$ – the matrix of import shipments of goods (cargo) i by modes of transport to the region r across the border, passing in the rr region;

$EX^{MAR}_{i,r,rr}$ –multimodal transportation of goods (cargo) i from region r with transshipment to maritime transport in the region rr by road, inland waterway and rail transport;

$EX^{IWW}_{i,r,rr}$ –multimodal transportation of goods (cargo) i from the region with transshipment to inland water transport in the region by road and rail transport;

$EX^{RAIL\to MAR}_{i,r,rr}$ – transshipment of export goods (cargo) i, delivered from the region r to the seaport located in the region rr by rail;

$EX^{IWW\to MAR}_{i,r,rr}$ – transshipment of export goods (cargo) i, delivered from the region r to the seaport located in the region rr by inland water transport;

$EX^{TRUCK\to MAR}_{i,r,rr}$ – transshipment of export goods (cargo) i, delivered from the region r to the seaport located in the rr region, by road;

$IM_{i,r,rr}^{MAR}$ –multimodal transportation of goods (cargo) i, arrived across the border of Russia to the region by maritime transport, for transshipment to other modes of transport and further transportation to regions of destination rr;

$IM_{i,r,rr}^{IWW}$ –multimodal transportation of goods (cargo) i, arrived via the Russian border in the region by inland water transport for transshipment to other modes of transport and further transportation to the regions of destination rr;

$IM_{i,r,rr}^{MAR \to RAIL}$ –multimodal transportation of goods (cargo) i, arrived across the border of Russia to the region by maritime transport for transshipment to rail transport and further transportation to the regions of destination rr;

$IM_{i,r,rr}^{MAR \to TRUCK}$ –multimodal transportation of goods (cargo) i, arrived across the border of Russia to the region by maritime transport for transshipment into road transport and further transportation to the regions of destination rr;

$IM_{i,r,rr}^{MAR \to IWW}$ –multimodal transportation of goods (cargo) i, arrived across the border of Russia to the region by maritime transport for transshipment to inland waterway and further transportation to the regions of destination rr;

$IM_{i,r,rr}^{IWW \to RAIL}$ –multimodal transportation of goods (cargo) i, arrived via the Russian border in the region by inland water transport for transshipment to rail transport and further transportation to the regions of destination rr;

$IM_{i,r,rr}^{IWW \to TRUCK}$ –multimodal transportation of goods (cargo) i, arrived via the Russian border to the region by inland water transport for transshipment to road transport and further transportation to the regions of destination rr.

$TR_{i,r,rr}^{RAIL}$ – transshipment of goods (cargo) i, within the region r from road to rail and from rail to road.

Equation (1) describes the statement that all produced goods must be transported within the region, or to other regions, or for export. Equations (2), (3) and (4) fix the geographical splitting of exports, imports and domestic goods flows, respectively. Equation (5) is the basic transport balance equation related to the multimodal transport. Equations (6) and (7) determine the procedure for estimating combined export traffic on the maritime and inland water transport, respectively. Equations (8) and (9) determine the procedure for estimating multimodal import traffic involving maritime and inland water transport, respectively.

4 Construction of the Transport and Economic Balance

The source data for TEB construction is the statistical data of Rosstat on the volumes of shipped products of mining and manufacturing industries, trade, construction industry, agriculture, export and import statistics including data from the Federal Customs Service of Russia (FCS of Russia), economic statistics of the fuel and energy complex, as well as transport statistics, including data from Russian Railways, statistics on maritime and inland water transport, road transport.

Industry-specific sources of information are used to construct the TEB matrix of products shipment and origin-destination transportation matrix for the regions of the

country. The Rosstat forms are used to compile shipping data, the Russian Railways corporate data warehouse (shipment archive), the maritime transport data of the M-3 and MP-2 forms, the inland water transport - data forms 11-W and 15 W. To determine the foreign trade transportation by road, the data of the Federal Customs Service of Russia is used; internal transportation by road is estimated on the basis of the data from the forms 1-export, П-1, 21-СХ and the above-mentioned statistics by the modes of transport.

All the initial information is structured and converted to a harmonized cargo nomenclature of the TEB ensuring the comparability and compatibility of all elements of the source data with each other.

The TEB harmonized cargo nomenclature includes the following 44 types of cargo:

- 1 *construction materials*
- 11 sand, gravel and stone
- 12 cement
- 13 construction Materials (bricks, blocks, glass and other except wood materials)
- 14 firelcays and heat resistant materials
- 2 *coal, coke, peat and shale*
- 21 coal
- 22 coke
- 23 peat and shale
- 3 *oil cargo*
- 31 crude oil
- 32 light petroleum products (gasoline, diesel fuel, kerosene, etc.)
- 33 heavy petroleum products (mazut, etc.)
- 34 compressed or liquefied gas
- 4 *ore*
- 41 ferrous metal ore
- 42 non-ferrous metal ore and other ore
- 5 *ferrous material*
- 51 rolled stock of ferrous metals
- 52 steel pipes
- 53 other ferrous metals
- 6 *fertilizers*
- 61 mineral and chemical fertilizers
- 62 raw mineral and chemical fertilizers (ore)
- 63 organic fertilizers
- 7 *timber cargo*
- 71 roundwood (round logs)
- 72 wood process products
- 8 grain and grind products
- 81 grain
- 82 grinding products

- 9 *other cargo*
- 91 chemicals and soda
- 92 non-ferrous metals and products from them
- 93 fluxes
- 94 hardware and metal construction materials
- 95 cellulose
- 96 cardboard, paper, printing products
- 97 agricultural products
- 98 compound feedstuff
- 99 food and drink products (except for mixed fodder)
- 9A sugar
- 9B scrap metal, other recyclables, waste
- 9B1 ferrous scrap
- 9B2 non-ferrous scrap
- 9B3 recyclables, waste, garbage
- 9C textiles, garment production
- 9D leather, leather goods and shoes
- 9E rubber products
- 9F other non-metal products not included in other groups
- 9G hardware, machinery and equipment
- 9H vehicles
- 9I electrical equipment, electronic and optical equipment
- 9J other goods not included in other groups

Exports and imports of goods (products) for regions of Russia are estimated on the basis of harmonized industrial statistics and foreign economic statistics. The volume of cargo load in the regions is estimated on the basis of production data. Interregional origin-destination transportation matrix for the regions and intraregional volumes of transportation are generated on the basis of transport statistics.

The balance is constructed for all regions of Russia. The calculations are based on the existing practice of statistical accounting in Russia without expensive additional surveys. The sequence of TEB formation is determined by the peculiarities of statistical accounting, the completeness and accuracy of the available source data on production, product shipment, trade and transportation of goods.

It should be mentioned that in Russia there is a well-established statistical accounting of production and interregional trade, as well as transport by modes of transport, but the quality of individual indicators is quite different. At the same time, in each industry and on each mode of transport, statistical recording implies its historically established range of goods (cargo) and its own level of spatial detail of statistical data.

Undoubtedly, the statistics of rail transportation is the best in Russia, it is known for the detailed cargo nomenclature and accounting origin-destination information detailed to the level of stations. These statistics are reliable and easily aggregated at the regional level into TEB harmonized cargo nomenclature. It is important that rail-

way transport provides the vast majority of all cargo turnover in Russia (excluding pipeline transportation).

According to Rosstat, in 2016 the freight turnover of railway transport was 10 times higher than that of road transport, 36 times the domestic water transport and 54 times the cargo turnover performed by Russian enterprises of maritime transport (excluding foreign). The only drawback of the railway statistics is the lack of information on the transshipment of goods from the railway to the road and back. This deficiency is compensated partially by the fact that it is known which enterprises have direct access to the public and nonpublic railways.

The statistics of interport maritime transportation is a little bit less convenient, but still reliable. It is carried out on the basis of consignment notes and therefore is reasonably accurate, easily regionalized, but due to the narrow range of goods, it can be reflected without loss only to the abbreviated TEB harmonized cargo nomenclature. When described in the expanded nomenclature, there are losses in the quali-ty of information, fortunately it has been empirically revealed that they are small. The advantage is the fact that the statistical accounting of cargo handling from the maritime to other modes of transport and back is adjusted.

Reliable is the statistics of production and shipment of large and medium-sized enterprises. The quality of statistics on small enterprises is not so good, but the contribution of small enterprises to the overall cargo shipment of Russia is small, and the methodology for its assessment is stable enough to consider this information conditionally reliable. Regardless of the number of enterprises covered by Rosstat surveys, the statistics of production and shipment of enterprises are easily region-alized and aggregated into the TEB nomenclature without loss.

The statistics of interregional trade in industrial and food products, raw materials and main types of agricultural products is convenient for the purposes of TEB. These statistics are also well regionalized and aggregated into the TEB without loss. Unfortunately, it covers only large and medium-sized enterprises and is not always accurate from a transport point of view. The reason is that the records are kept at the location of the buyer and seller of products, which, under Russian conditions, does not always reflect the actual location of the sender and receiver of the goods. A positive point is that the statistics of trade in the most important for Russia fuel and energy resources and fuel, maintained by Rosstat, is reliably and significantly more closely duplicated by the subordinate organizations of the Ministry of Energy of Russia.

The statistics of inland water transport is much less convenient for the purpose of forming the TEB. The advantage of this statistics is that it represents the OD-matrix of interregional transport by inland water transport. But this statistic has a number of significant drawbacks. First, it relies solely on the declarations of transportation by professional market participants, that is, organizations that declare inland water transport as the main activity. Meanwhile, significant volumes of transportation of timber and petroleum products are carried out by branches of organizations that have a main type of activity that differs from inland water transport. This gives them the opportunity not to be covered by statistical observation. The second drawback is the extremely narrow range of goods, which is recorded. Until 2017, statistics on interregional inland water transport was carried out for only 4 types of cargo. Since 2017, it

is conducted on 10 types of cargo. This gives some inaccuracies in converting to TEB cargo nomenclature. Nevertheless, the advantage is that there is a statistics of transshipment of goods to other modes of transport and back for inland water transport.

The statistics of road transport is the worst in all senses. Until 2017, it did not include division by type of cargo. There is no assessment by Rosstat of the volumes of interregional transportation by road. There is only an estimate of the total volume of transportation by industry in the regions, but it also causes some confidence only in large and medium-sized enterprises. The situation is complicated by the fact that transportation by motor vehicles performed by small and micro enterprises, as well as individual entrepreneurs in the Russian context cannot be neglected, since their share in the road transport market is greater than that of large and medium-sized enterprises.

Thus, the statistical accounting of production, shipment, trade and transportation in Russia determines the specific sequence of TEB calculation.

First of all, when processing initial information, it is necessary to take into account that all sections of statistics may contain errors and inaccuracies. In addition, from year to year, the statistical accounting system in Russia is changing, new accounting rules, codes and indicators are introduced, which require special processing before performing the TEB calculations.

When converting input forms of statistical accounting to a form suitable for machine processing, the TEB operator eliminates obvious errors associated, for example, with the dimension of quantities, units of measurement, incorrect representation of numerical values, etc. Next, an analysis of changes in the regulatory and reference information of statistical accounting is carried out, if the statistical monitoring bodies enacted the changes last year. In order to take these changes into account, a special mechanism is provided to ensure the unification of the original statistical data and bring them to a universal internal form for presenting information on the production and transportation of cargo-intensive products. This mechanism is implemented using the tables of keys for conversion information from the source form to universal harmonized cargo nomenclature used in TEB. Conversion keys provide mapping of the initial information on cargo loading volume and cargo transportation to the internal TEB tables using a harmonized cargo nomenclature. When changing the original forms of statistical accounting, the operator configures the tables of conversion keys, which provide the ability to automatically download and process the initial statistical information for performing the TEB calculations.

Logical control of the initial statistical information is performed while preparing for the calculations. For example, the sums of various quantities in the regions are compared with similar values for Russia as a whole, as well as each other of identical data from different statistical forms are compared also. In case of discrepancy of these data, the operator clarifies the values of the original statistical information with the organization, which is the source of information. The calculation of TEB is performed as follows. First, on the basis of economic statistics, the cargo loading volume of in-

dustry, agriculture, trade, and also the recycling industry is calculated. Then, according to transport statistics, using the balance equations of the TEB (1) - (9), an estimate of the interregional transportation by rail, maritime and inland water transport is compiled.

The total volume of interregional transportation by road, including intraregional transportation (for itself), is estimated initially as the difference in the cargo loading volume (production output) and transportation by other modes of transport. Then for each interregional correspondence for each type of cargo from the difference in the known volumes of interregional trade and volumes of interregional transportation by rail, inland water and maritime transport, the volume of interregional transportation by motor transport is estimated. Other road transportation is considered as intraregional transportation (for itself). Multimodal transportation by rail, inland waterway and road transport is estimated using the statistical proportions of export of products produced by one or another type of transport, as well as balance equations of the TEB.

From the standpoint of the freight turnover of motor vehicles, the OD-matrix of interregional motor transportation obtained in this way can be considered a conservative estimate. This OD-matrix is refined using actual data on the intensity of the movement of vehicles on highways. The refining is performed by solving the optimization problem of minimizing the discrepancy of the estimated intensity of traffic and actual data on the intensity of movement of vehicles. The estimation of interregional origin-destination flows by road transport is specified to an upper value by reassigning a part of transportation previously assigned to intraregional carriages to interregional transportation.

The resultant TEB is represented by spatial input-output tables. It aggregates the actual and forecast origin-destination flows of freight traffic (OD-matrix) between the regions of the Russian Federation by all modes of transport by types of commodities described in terms of harmonized cargo nomenclature. This matrix accurately reflects the structure of interregional transportation by rail, inland water and maritime transport and successfully reflects the structure of interregional transportation by road. At least, the traffic estimation of road transport is consistent with the volume of shipments in Russia, transportation by other modes of transport and data from the traffic metering points on the roads. This means that the TEB is fairly accurate in general.

At the final stage of TEB calculation the results are checked and verified. The discrepancies of the balance are identified taking into account the balance equations of TEB (1) - (9). The obtained estimates of cargo transportation by types of commodities are compared with similar data from previous years. When large discrepancies and deviations are detected the input data is checked against the original data, the information processing errors are detected and the data is refined with provider. After the elimination of errors the transition to recalculation of the refined TEB is done.

The consolidated balance describes the departure and arrival of goods in the regions of Russia. The shipment balance reflects the shipment from some region to other regions of Russia and for export, and the arrival balance describes the arrival of goods in the region from other regions of Russia and by import. A consolidated spatial input-output table of domestic transportation of goods for the region by modes of

transport, as well as a table of transportations from the region in export and import by modes of transport is built.

The results are implemented in the Information and Analytical System for Transport Regulation of the Ministry of Transport of the Russian Federation. The constructed transport and economic balance describes the actual and forecast volumes and origin-destination information of 97% of freight traffic between all the regions of the Russian Federation. The discrepancies in the initial data caused by the incompleteness and inaccuracy of the original statistics were corrected when constructing the balance. The criterion for eliminating discrepancies is the convergence of balance equations between regions, as well as for export and import.

The interregional discrepancy averages 3-5%, that is, the balance has an accuracy of 95%. Discrepancies are caused by inaccuracy and incompleteness of official statistical information and differences in accounting technology for various statistical forms, as well as small errors in converting data to unified cargo (product) accounting units used in TEB.

The forecast of cargo load and interregional freight flows of TEB covers the period up to 2030. The forecast model uses economic parameters and scenario conditions of the Ministry of Economic Development of Russia, as well as regional economic development scenarios.

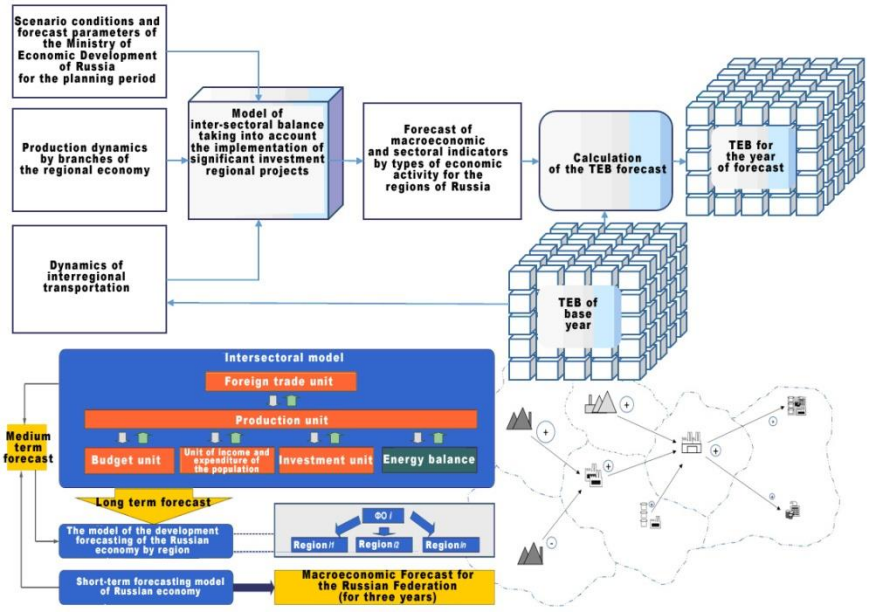

Fig. 8. Forecasting model in the transport and economic balance.

The software forecast model takes into account changes in technological and transport connectivity of main cargo generating industries, reflecting the technological links of these industries with resource suppliers and consumers of their products.

At the same time, the forecast model uses the direct cost matrix of the symmetrical input-output table (inter-sectoral balance) for Russia as a whole.

5 The Application of the Transport and Economic Balance

Actual and forecast TEB describing spatial input-output tables of transportation demand between territories of the country as well as export and import by types of commodities and means of transport provides a large amount of important information for transport planning.

TEB forecast together with current transport infrastructure data provides an assessment of imbalances in the use of various types of cargo transport, identification of cargo-intensive transport directions, determination of measures for switching traffic flows to the most profitable for society types of transport and development of the transport infrastructure capacity. For example, in planning of international transport corridors development (ITCs) for these purposes, along with TEB, an electronic passport ITC (EP ITC) can be used [2].

The TEB provides the basis for calculation and justification of the predicted loads on the infrastructure taking into account various options for its reconstruction and development. It will help to optimize distribution of the predicted flows through the network taking into account future characteristics of throughput, speeds and stability (predictability) of cargo delivery time, loading of network elements and bottlenecks. The most effective projects will be ranked and prioritized on this basis. Freight flows optimization criterion include price, time, reliability and safety of transportation, impact on the environment, taking into account capacity constraints. At the same time, the variation of tariffs makes it possible to evaluate various options for the redistribution of flows along the transport network.

Transport planning for certain territories and routes could use the following steps: analysis of the cargo load and traffic flows, search for imbalances, formation of project activities for specific territories and routes, calculation of key performance indicators for each solution, calculation costs and effects, including multiplicative effects in the economy, the selection of the most effective solutions via "cost-benefit analysis". Calculations can take into account various economy scenarios, different transport demand scenarios and types of commodities.

References

1. Evseev, O., Zaboev, A.: Prospects of electronic passportization of transport corridors in the EAEU within the context of transport digitalization [in Russian]. In: Prospects for the development of the transport complex, pp. 9-12. BelNIIT, Minsk (2017)
2. Evseev, O.V., Murashov, V.V., Zaboev, A.I., Zemtsov, A.A., Buslov, V.N., Shubin, Al.V., Schirov, A.A., Shubin, An.V., Urazov, A.S., Anikina, E.: Transport and Economic Balance and Its Role in the Coordination of Transport Planning during the Digitalization Era [in Russian]. Modern Information Technology and IT-education **14**(3), 717-716 (2018). doi: 10.25559/SITITO.14.201803.717-726

3. The use of mathematical methods and computers in planning the development and operation of transport [in Russian]. In: Chernomordik, G.I., Kozlov, I.T. (eds.). Transport, Moscow (1967)
4. Kovshov, G.N.: Transport in the system of long-term planning models of the national economy. Economics and mathematical methods [in Russian]. **XIII**(5), pp. 1034-1053. Moscow (1977)
5. Kovshov, G.N., Mikhailov, A.D.: About the transport factor in the system of optimal long-term planning of the national economy [in Russian]. In: Optimal planning challenges. Part II. CEMI USSR Academy of Sciences, Moscow (1973)
6. Livshits, V.N.: The choice of optimal solutions in the technical and economic calculations [in Russian]. Economics, Moscow (1971)
7. Methodical foundations for building a system of models of national economic planning in a sectoral and territorial context [in Russian]. CEMI USSR Academy of Sciences, Moscow (1980)
8. Transport strategy of the Russian Federation for the period up to 2030 of 22.11.2008 no. 1734-r as amended by the Order of the Government of the Russian Federation of 11.06.2014 no. 1032-r [in Russian]. In: collection of legislation of the Russian Federation no. 50, art. 5977, https://www.mintrans.ru/documents/3/1009, last accessed 2018/08/12.
9. Shirov, A.A., Yantovsky, A.A.: Input-output macroeconomic model as the core of complex forecasting calculations. Studies on Russian Economic Development **25**(3), 225-234 (2014)
10. Brandsma, A., Ivanova, O., Kancs, d'A.: RHOMOLO – a dynamic spatial general equilibrium model. JRC IPTS, Seville, Spain (2011)
11. Ivanova, O.: The role of transport infrastructure in regional economic development. In: TØI Report 671/2003. Oslo (2003) https://www.toi.no/getfile.php?mmfileid=9223
12. Ivanova, O., Vold, A., Jean-Hansen, V.: PINGO: A model for prediction of regional and interregional freight transport. In: Version 1. TØI rapport 578/2002. Oslo (2002) https://www.toi.no/getfile.php?mmfileid=2346
13. Commodity Flow Survey Overview. U.S. Department of Transportation, Bureau of Transportation Statistics, https://www.bts.gov/cfs, last accessed 2018/08/12.
14. Core Database Development for the European Transport policy Information System (ETIS). EU Transport Research and Innovation Monitoring and Information System, https://trimis.ec.europa.eu/?q=project/core-database-development-european-transport-policy-information-system-etis, last accessed 2018/08/12.
15. Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M., de Vries, G.: The construction of World Input-Output Tables in the WIOD project. Economic Systems Research **25**(1), 71-98 (2013) doi: 10.1080/09535314.2012.761180
16. Fachin, S., Venanzoni, G.: IDEM: an Integrated Demographic and Economic Model of Italy. In: Proceedings of the 14th International Conference on Input-Output Techniques. CONSIP S.p.A. (2002) https://www.iioa.org/conferences/14th/files/Fachiim.pdf
17. Gaulier, G., Zignago, S.: BACI: International Trade Database at the Product-Level. In: The 1994-2007 Version. CEPII Working Paper 2010-23. (2010) http://www.cepii.fr/CEPII/en/publications/wp/abstract.asp?NoDoc=2726
18. Helpman, E., Melitz, M., Rubinstein, Y.: Estimating Trade Flows: Trading Partners and Trading Volumes. The Quarterly Journal of Economics **123**(2), 441-487 (2008) doi: 10.1162/qjec.2008.123.2.441
19. Lenzen, M., Moran, D., Kanemoto, K., Geschke, A.: Building EORA: A global multi-region input-output database at high country and sector resolution. Economic Systems Research **25**(1), 20-49 (2013) doi: 10.1080/09535314.2013.769938

20. Narayanan, G., Badri, A.A., McDougall, R.: Global Trade, Assistance, and Production: The Gtap 8 Data Base. Purdue University, Center for Global Trade Analysis (2012) https://www.gtap.agecon.purdue.edu/databases/v8/v8_doco.asp
21. Measuring Material Flows and Resource Productivity. In: Vol. I. The OECD Guide. OECD (2008) https://www.oecd.org/environment/indicators-modelling-outlooks/MFA-Guide.pdf, last accessed 2018/08/12.
22. STAN Database for Structural Analysis. Organisation for Economic Cooperation and Development (OECD). In: ISIC Rev. 3, SNA93. https://stats.oecd.org/index.Aspx?Datasetcode=stan08bis, last accessed 2018/08/12.
23. Sivakumar, A.: Modelling transport: A Synthesis of Transport Modelling Methodologies. Imperial College London Working Paper (2007)
24. Sorratini, J.A.: Estimating Statewide Truck Trips Using Commodity Flows and Input-Output Coefficients. Journal of Transportation and Statistics **3**(1), 53-67 (2000) https://www.bts.gov/sites/bts.dot.gov/files/legacy/publications/journal_of_transportation_and_statistics/volume_03_number_01/jts_v3_n1.pdf
25. Global Material Flows Database, http://www.Materialflows.net, last accessed 2018/08/12.
26. Heyndrickx, Ch., Kartseva, M., Tourdyeva, N.: The SUST-RUS database: regional social accounting matrix for Russia. In: SUST-RUS Project Report (2011) http://www.cefir.ru/index.php?l=eng&id=528, last accessed 2018/08/12.
27. Tukker, A., Poliakov, E., Heijungs, R., Hawkins, T., Neuwahl, F., Rueda-Cantuche, J.M., Giljum, S., Moll, S., Oosterhaven, J., Bouwmeester, M. Towards a global multi-regional environmentally extended input-output database. Ecological Economics **68**(7), 1928-1937 (2009) doi: 10.1016/j.ecolecon.2008.11.010
28. United Nations Statistics Division. In: UN Comtrade – United Nations Commodity Trade Statistics Database. New York, NY, USA, United Nations Statistics Division (UNSD) (2012) https://unstats.un.org/unsd/databases.htm, last accessed 2018/08/12.
29. United Nations Statistics Division. In: United Nations Service Trade Statistics Database. New York, NY, USA, United Nations Statistics Division (UNSD) (2017) https://unstats.un.org/unsd/databases.htm, last accessed 2018/08/12.