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Simulation modeling of changes in demand for rail transportation

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Abstract. The purpose of the paper is to justify the use of the intersectoral balance model for forecasting the demand for rail transportation in the face of significant changes in commodity markets. The theoretical basis of the study is the algebraic theory of the analysis of the input-output model. The methodology is based on the balance method. The modeling procedure comes down to solving a system of linear equations in which the coefficients are cost coefficients for production. The modeling information base includes scenario conditions for forecasting the socio-economic development of 40 industries and activities for which rail transportation is of decisive importance, and whose share in the structure of the GDP of Russia for the period until 2036 will change slightly. The main results of the study are: the implemented process of modeling demand for rail transportation, including a basic simulation of the intersectoral balance of the Russian economy for 2016, a predicted simulation model of demand for the period until 2030. An assessment was made of a long-term change in demand for rail transport services, taking into account structural changes affecting the activities of the main sectors of the national economy, which products are changing interspecific competition, the emergence of new product markets and digital technologies.

1. Introduction

The adoption of managerial decisions in the field of long-term investment development and territorial distribution of railway transport infrastructure is based on the use of a large-scale information base used in conjunction with advanced scientific and methodological planning and forecasting approaches.

Macroeconomic scenarios developed for the medium and long term by the Ministry of Economic Development of the Russian Federation [3] are mainly used as sources of information for making forecasts of volumes of cargo transportation and the number of passengers carried. At the same time, data are taken into account from industry documents of strategic planning, various government projects and programs in the field of transport development, and materials from competent expert analytical agencies [2, 5, 6]. Another important source of information is the results of inquiries received from major shippers regarding their strategic plans for the production of goods and, therefore, changes to the cargo base.

At the same time, the forecast indicators for the development of individual industries and the announced plans of shippers are generally optimistic and do not correspond to real trends in the development of industries and the economy as a whole. In some cases, the data received from companies, as well as regions, are not consistent and contradict each other. As a result, the forecast obtained on the basis of this information is rather distorted and overestimated relative to the real volumes of the railway network load.

Thus, the building of forecasts for the development of railway transport, based only on an assessment of the dynamics of individual industries and companies, has drawbacks. Other more advanced scientific and methodological approaches to forecasting the volume of transportation activity are needed, which are based on the study of structural proportions and interrelations of economic sectors, taking into account estimates of changes in other modes of transport, transportation tariffs, and territorial structural changes in industry development.

The solution to this problem is the use of scientifically-based forecasting tools with the building of a simulation model of intersectoral balance (ISB). The basic ISB model should be organically supplemented with simulation models of inter-regional balance for the transport of goods and passengers.

The purpose of the study is the methodological justification and building of a forecast model of the intersectoral balance of the Russian economy for the period until 2030, which will act as a scientifically-based tool for substantiating strategic decisions in the field of railway transport development. The purpose of the study is implemented through the following steps: building a simulation model of the intersectoral balance of the Russian economy in the base year (the period of 2016 is taken as the base) and developing a forecast model of the intersectoral balance of the Russian Federation for the period until 2030, in which the forecast of demand for rail transport services will be a key element.

2. Materials and Methods

Intersectoral balance tables are used to assess the relationship between industries. Such tables were first published in 1926 in Russia. The mathematical model of the intersectoral balance, which admits ample opportunities for analysis and forecasting, appeared in the writings of the American economist Vasily Leontief in 1936. In this case, each industry acts, on the one hand, as a producer of certain products (a provider of certain services), and on the other hand, as a consumer of products and services produced by other industries. The intersectoral balance is also called the Leontief model or the input-output model). The methodology of this study is based on the balance method or the method of analysis and comparison of opposing and balancing factors.

The algebraic theory of the analysis of the input-output model comes down to solving a system of linear equations in which the coefficients of the cost of production are parameters.

The main equation of the model is the so-called balance equation:

$$AX + Y = X,$$

where X is the vector (matrix) of gross output of all “pure” sectors of the economy; Y is the vector (matrix) of final use of products and services of industries (includes gross fixed capital formation, end use of products and services, net export of the industry); A - matrix of direct cost coefficients; its elements reflect the volume of resources consumed by industry i for the production of a unit of products (services) by industry j; x_{ij} – the volume of industrial consumption of products of industry i in industry j (($x_{ij} = a_{ij} * X_j$, where a_{ij} is an element of the matrix of direct cost coefficients). Moreover, the following indicators are calculated in the ISB model: 1) gross value added: $Z_{ij} = X_j - \sum x_{ij}$, where X_j is the output of products (services) by industry j; $\sum x_{ij}$ - the sum of the costs of intermediate consumption of all sectors that were implemented in the production of products (services) of sector j; 2) the final demand for the products of Y_i services as the difference between the gross output X_i and the intermediate consumption of products (services) - the sum of deliveries by this industry to other consumer sectors $\sum x_{ij}$: $Yi = X_i - \sum x_{ij}$.

It is necessary to take into account the existing official forecasts for the development of the transport industry within the framework of the basic forecast prepared by the Ministry of Economic Development of the Russian Federation in November 2018 (scenario conditions for the forecast of socio-economic development of the Russian Federation for the period until 2036). The forecast parameters of the transport industry sectors until 2030 are shown in Figure 1.

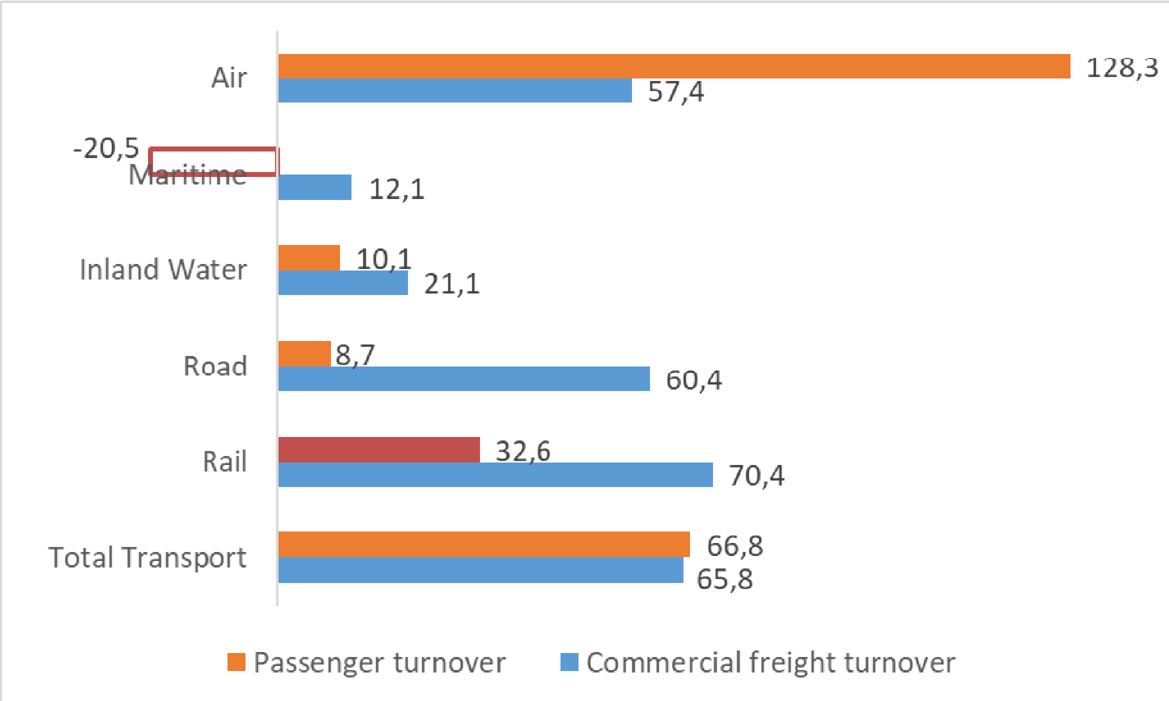

Figure 1. Forecast of growth in freight and passenger turnover of various modes of transport in the Russian Federation in 2030 compared to 2016, %. Source: Ministry of Economic Development of the Russian Federation [3].

When building the ISB simulation model, from a large list of industries and activities (more than 150) we selected 40 species for which rail transportation is of great importance in the cost structure (the first 40 sectors leading in the structure of supply of railway transport services, selected according to the criterion of direct cost coefficients). The remaining sectors of the economy are grouped into a common block “other sectors”. This will bring the model into a more convenient form for study. Figure 2 shows the initial data for making forecasts relating to specific forecasted indices of gross output change in key industries - consumers of railway transport services.

The estimates of the Ministry of Economic Development [3] give an idea of the dynamics of cargo shipments in various industries. The most promising dynamics characterize the development of such industries as: production of vehicles (2.6 times by 2030 compared to 2016), chemical products (2.2 times), recycled production (90%), products of flour and cereal industry (by 78%), pulp and paper production (by 77%). The lowest growth rates, according to forecast estimates, are expected in: production of petroleum products (by 34%), non-ferrous ores (46%), coal production (40%), timber harvesting (36%), sawn timber production (37%), coke products production (36%).

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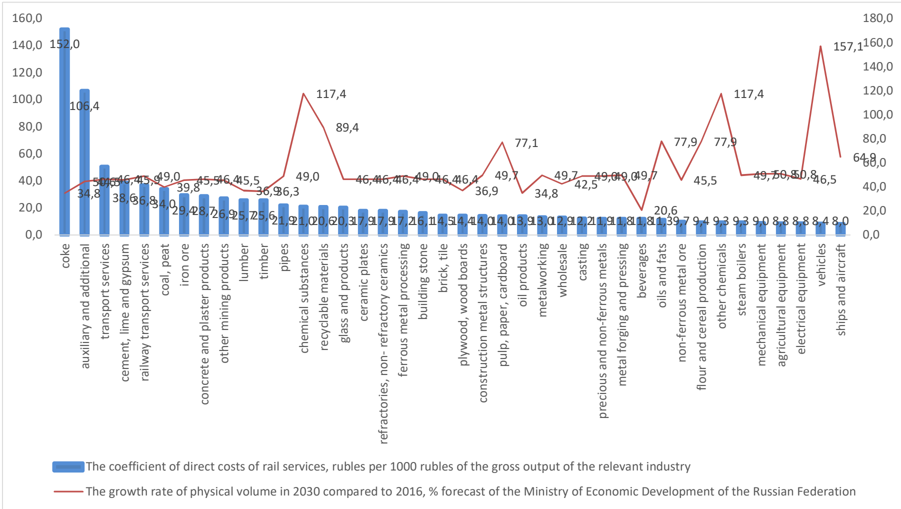

Figure 2. Dynamics of the percentage increase in the physical volume of production of goods, provision of services in industries - key consumers of railway transport services, in 2030 compared to 2016.Source: Ministry of Economic Development of the Russian Federation - forecast up to 2036; basic input-output tables for 2016 prepared by Russian Federal State Statistics Service (Rosstat) for 2016 [1, 3].

3. Results

As a result of data processing, a matrix of direct cost coefficients is formed, in which its elements are estimates of the volumes of products (services) of one industry for the production of a unit of products (services) of another industry. The initial information for the calculations in the simulation model is the data of the Rosstat reporting interindustry balances for previous years (the latest balance sheet was prepared for 2016).

An assessment of the matrix of direct cost coefficients is shown in Table 3.

Table 1. Matrix of direct cost ratios (fragment) - rubles per 1000 rubles of gross output of goods (services) of the relevant industry.

Consumer industries / supplier industries	timber	coal, peat	Iron ore	non-ferrous metal ore	other mining products	oils and fats	flour and cereal production	beverages	lumber	plywood, wood boards	pulp, paper, cardboard
timber	74.50	0.18	0.02	0.16	0.05	0.00	0.03	0.39	194	120	49.70
coal, peat	0.40	126	0.17	4.42	0.80	0.45	0.51	0.13	1.15	0.17	7.34
iron ore	0.00	0.11	4.87	0.96	0.86	0.00	0.00	0.00	0.00	0.00	0.00
non-ferrous metal ore	0.01	0.01	0.47	14.74	0.21	0.00	0.00	0.00	0.03	0.00	0.00
other mining products	0.92	0.86	2.62	1.17	14.84	0.77	1.42	0.18	0.30	0.46	0.63
oils and fats	0.04	0.01	0.00	0.01	0.00	141	36.3	0.40	0.03	0.00	0.00

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flour and cereal production	0.15	0.01	0.00	0.02	0.01	3.66	14.96	2.56	0.04	0.27	0.46
beverages	0.01	0.01	0.00	0.01	0.00	0.07	0.08	66.17	0.01	0.00	0.00
lumber	3.36	0.46	0.15	0.15	0.21	0.10	0.20	0.07	58.27	11.14	8.02
plywood, wood boards	0.49	0.06	0.00	0.06	0.10	0.00	0.01	0.01	2.44	28.66	0.05
pulp, paper, cardboard	2.44	0.07	0.04	0.13	0.52	0.92	0.72	3.11	1.55	38.70	72.64
coke	0.01	0.03	2.97	0.58	0.70	0.00	0.07	0.00	0.05	2.93	0.01
oil products	93.21	45.77	25.70	46.08	62.30	3.22	8.02	4.17	41.00	12.74	18.47
chemical substances	2.77	0.89	2.50	9.42	2.07	9.56	6.85	18.90	5.60	89.16	32.22
other chemicals	0.38	0.68	0.82	1.10	1.49	2.11	1.19	4.08	6.07	12.38	1.30
glass and products	0.08	0.04	0.01	0.05	0.16	0.51	0.12	49.31	0.54	0.47	0.03
refractories, non- refractory ceramics	0.16	0.07	0.11	0.30	0.69	0.01	0.04	0.03	0.03	0.03	0.01
…	…	…	…	…	…	…	…	…	…	…	…
wholesale	39.64	25.64	12.21	24.67	22.16	56.58	92.90	70.22	106	86.07	62.79
railway transport services	**25.61**	**33.97**	**29.36**	**9.70**	**26.95**	**11.26**	**9.40**	**11.81**	**25.74**	**14.43**	**13.98**
auxiliary and additional transport services	18.66	29.61	22.68	7.05	27.56	10.96	17.19	11.46	18.35	8.91	10.88
other industries	164	176	166	173	222	479	509	326	146	159	184

Table 2. Matrix of direct cost ratios (fragment) - rubles per 1000 rubles of gross output of goods (services) of the relevant industry. Source: authors' calculations based on [1].

Consumer industries / supplier industries	coke	oil products	chemical substances	other chemicals	glass and products	refractories, non-refractory ceramics	…	wholesale	railway transport services	auxiliary and additional transport services	other industries
timber	0.00	0.00	0.31	0.04	0.01	0.31	…	0.02	**0.40**	0.10	0.37
coal, peat	515	0.00	3.01	4.76	0.08	0.21	…	0.74	**1.32**	0.55	1.78
iron ore	15.08	0.00	1.39	2.44	0.00	0.11	…	0.00	**0.18**	0.07	0.05
non-ferrous metal ore	0.65	0.01	1.96	0.31	0.09	10.11	…	0.00	**0.03**	0.04	0.02
other mining products	0.33	0.14	20.67	5.81	29.41	69.57	…	0.11	**0.51**	3.01	1.69
oils and fats	0.00	0.00	0.01	0.26	0.00	0.00	…	0.17	**0.11**	0.08	1.20
flour and cereal production	0.00	0.00	0.02	0.02	0.60	0.27	…	0.03	**0.05**	0.35	1.27
beverages	0.00	0.00	0.37	0.34	0.01	0.13	…	0.02	**0.02**	0.20	0.29
lumber	0.04	0.00	0.22	0.26	3.49	1.79	…	0.06	**1.38**	1.14	0.43
plywood, wood boards	0.00	0.00	0.02	0.00	0.05	0.03	…	0.06	**0.01**	0.08	1.28
pulp, paper, cardboard	0.03	0.03	0.42	1.31	0.91	0.95	…	0.61	**0.33**	0.71	1.91
coke	4.04	0.31	2.00	1.68	3.02	0.56	…	0.02	**0.06**	0.03	0.07
oil products	2.49	121	127	48.98	12.05	9.21	…	3.85	**30.16**	45.14	15.26
chemical substances	6.27	9.91	95.5	88.3	78.9	29.4	…	0.40	**0.39**	0.84	6.99

			9	5	0	1					
other chemicals	0.56	5.55	11.38	43.98	2.62	1.88	…	0.56	**0.53**	0.64	1.37
glass and products	0.00	0.00	0.19	0.19	76.06	0.43	…	0.06	**0.18**	0.09	0.67
refractories, non- refractory ceramics	1.37	0.01	0.27	0.32	9.08	68.67	…	0.01	**0.09**	0.09	0.33
...	…	…	…	…	…	…	…	…	**…**	…	…
wholesale	81.28	22.36	47.01	42.26	53.65	45.02	…	27.17	**11.52**	13.67	33.50
railway transport services	**152**	**13.92**	**20.99**	**9.35**	**20.30**	**17.87**	**…**	**12.87**	**38.63**	**106**	**3.29**
auxiliary and additional transport services	35.62	39.17	22.43	8.07	15.32	7.82	…	35.45	**48.17**	87.95	8.08
other industries	78	491	187	117	242	180	…	250	**254**	267	276

Solving the balance equation (AX + Y = X, where the known values are: matrix of direct cost coefficients (A) and gross output vector (X) - the sum of the proceeds from the sale of products (services) in the relevant sectors), a basic intersectoral balance for 2016 was built - figure 4.

Table 3. Part 1 - Assessment of the intersectoral balance of goods and services in the Russian Federation for 2016, billion rubles (fragment).

Consumer industries / supplier industries	timber	coal, peat	Iron ore	non-ferrous metal ore	other mining products	oils and fats	flour and cereal production	beverages	lumber	plywood, wood boards	pulp, paper, cardboard	coke
timber	26.19	0.20	0.01	0.03	0.04	0.00	0.01	0.43	61.23	35.44	25.54	0.00
coal, peat	0.14	137.75	0.08	0.82	0.70	0.24	0.17	0.14	0.36	0.05	3.77	57.22
iron ore	0.00	0.12	2.32	0.18	0.76	0.00	0.00	0.00	0.00	0.00	0.00	1.68
non-ferrous metal ore	0.00	0.01	0.22	2.73	0.18	0.00	0.00	0.00	0.01	0.00	0.00	0.07
other mining products	0.32	0.94	1.25	0.22	13.03	0.41	0.49	0.20	0.09	0.14	0.32	0.04
oils and fats	0.01	0.01	0.00	0.00	0.00	74.69	12.47	0.44	0.01	0.00	0.00	0.00
flour and cereal production	0.05	0.01	0.00	0.00	0.01	1.93	5.13	2.78	0.01	0.08	0.24	0.00
beverages	0.00	0.01	0.00	0.00	0.00	0.04	0.03	71.72	0.00	0.00	0.00	0.00
lumber	1.18	0.50	0.07	0.03	0.18	0.05	0.07	0.08	18.40	3.29	4.12	0.00
plywood, wood boards	0.17	0.07	0.00	0.01	0.09	0.00	0.00	0.01	0.77	8.47	0.02	0.00
pulp, paper, cardboard	0.86	0.07	0.02	0.02	0.46	0.48	0.25	3.37	0.49	11.45	37.34	0.00
coke	0.00	0.03	1.41	0.11	0.62	0.00	0.03	0.00	0.02	0.87	0.01	0.45
oil products	32.77	50.11	12.22	8.54	54.70	1.70	2.75	4.52	12.94	3.77	9.49	0.28
chemical substances	0.98	0.97	1.19	1.74	1.82	5.05	2.35	20.48	1.77	26.37	16.56	0.70
other chemicals	0.14	0.75	0.39	0.20	1.31	1.12	0.41	4.42	1.92	3.66	0.67	0.06

glass and products	0.03	0.04	0.00	0.01	0.14	0.27	0.04	53.45	0.17	0.14	0.02	0.00
refractories, non- refractory ceramics	0.06	0.07	0.05	0.05	0.61	0.01	0.01	0.03	0.01	0.01	0.00	0.15
...	…	…	…	…	…	…	…	…	…	…	…	…
wholesale	13.94	28.08	5.81	4.57	19.46	29.88	31.88	76.11	33.42	25.45	32.27	9.03
railway transport services	**9.00**	**37.19**	**13.97**	**1.80**	**23.66**	**5.95**	**3.23**	**12.80**	**8.13**	**4.27**	**7.18**	**16.89**
auxiliary and additional transport services	6.56	32.42	10.79	1.31	24.19	5.79	5.90	12.42	5.80	2.63	5.59	3.96
other industries	57.83	193.03	79.10	32.13	195	253	175	353.27	46.19	47.10	94.71	8.72
Gross value added	**184.4**	**599.0**	**334.9**	**120.1**	**513.1**	**146.1**	**101.3**	**460.5**	**119.9**	**120.0**	**262.3**	**9.6**
Total resources at basic prices (gross output)	**351.6**	**1094.9**	**475.6**	**185.2**	**877.9**	**528.1**	**343.1**	**1084.0**	**315.7**	**295.7**	**514.0**	**111.1**

Table 4. Part 2 - Assessment of the intersectoral balance of goods and services in the Russian Federation for 2016, billion rubles (fragment). Source: authors' calculations.

Consumer industries / supplier industries	oil products	chemical substances	other chemicals	glass and products	refractories, non-refractory ceramics	…	wholesale	railway transport services	auxiliary and additional transport services	other industries	**Total intermediate consumption in industries**	**Final consumption expenses**	**Gross capital formation**	**Net export**	**Total final use (final demand)**	**Total use (gross output)**
timber	0.00	0.83	0.02	0.00	0.04	…	0.29	**0.73**	0.44	41.15	194.07	21	66	70	158	351.6
coal, peat	0.03	8.04	1.84	0.02	0.03	…	11.70	**2.40**	2.46	199.44	624.70	10	28	432	470	1094.9
iron ore	0.00	3.70	0.94	0.00	0.02	…	0.00	**0.33**	0.32	5.09	341.94	0	0	134	134	475.6
non-ferrous metal ore	0.04	5.22	0.12	0.02	1.36	…	0.00	**0.06**	0.16	2.31	142.24	0	5	38	43	185.2
other mining products	1.09	55.14	2.24	7.10	9.32	…	1.71	**0.93**	13.35	189.81	393.09	9	46	430	485	877.9
oils and fats	0.00	0.04	0.10	0.00	0.00	…	2.60	**0.20**	0.36	134.33	225.42	228	-3	78	303	528.1
flour and cereal production	0.00	0.05	0.01	0.14	0.04	…	0.53	**0.08**	1.53	142.50	155.49	153	4	30	188	343.1
beverages	0.02	0.99	0.13	0.00	0.02	…	0.28	**0.03**	0.89	32.19	106.89	934	23	20	977	1084.0
lumber	0.01	0.58	0.10	0.84	0.24	…	0.90	**2.51**	5.04	48.11	95.48	4	10	206	220	315.7
plywood, wood boards	0.01	0.07	0.00	0.01	0.00	…	1.00	**0.02**	0.37	143.29	157.95	9	11	118	138	295.7
pulp, paper, cardboard	0.26	1.13	0.50	0.22	0.13	…	9.63	**0.60**	3.13	214.15	300.61	3	16	195	213	514.0

coke	2.33	5.34	0.65	0.73	0.08	…	0.37	**0.11**	0.13	7.42	133.61	0	5	-27	-22	111.1
oil products	920.71	340.18	18.89	2.91	1.23	…	60.56	**54.90**	200.12	1714.00	3722.60	728	185	2991	3904	7626.9
chemical substances	75.57	255.07	34.08	19.04	3.94	…	6.35	**0.72**	3.74	785.17	1431.39	2	41	1193	1237	2668.3
other chemicals	42.32	30.37	16.96	0.63	0.25	…	8.85	**0.96**	2.85	153.38	325.54	18	21	21	60	385.7
glass and products	0.03	0.51	0.07	18.36	0.06	…	1.00	**0.33**	0.38	75.46	191.96	19	14	16	49	241.4
refractories, non-refractory ceramics	0.05	0.72	0.12	2.19	9.20	…	0.21	**0.17**	0.42	36.67	102.63	18	5	8	31	134.0
...	…	…	…	…	…	…	…	**…**	…	…	…	…	…	…	…	…
wholesale	170.57	125.45	16.30	12.95	6.03	…	426.82	**20.96**	60.61	3763.14	5889.69	4203	1328	4290	9821	15710.8
railway transport services	**106.16**	**56.02**	**3.60**	**4.90**	**2.40**	**…**	**202.15**	**70.31**	**471.85**	**370.00**	**1708.58**	**28**	**22**	**61**	**112**	**1820.1**
auxiliary and additional transport services	298.78	59.85	3.11	3.70	1.05	…	556.91	**87.67**	389.89	907.31	2554.50	778	0	1101	1879	4433.3
other industries	3744	497.67	45.00	58.35	24.09	…	3928.29	**462.76**	1183	31024	45779.39	44672	14916	6972	66561	112340
Gross value added	**2246.6**	**1180.4**	**235.5**	**102.5**	**69.2**	…	**10390.60**	**944.8**	**1928.8**	**68572.7**	**96918.9**					
Total resources at basic prices (gross output)	**7626.9**	**2668.3**	**385.7**	**241.4**	**134.0**	…	**15710.80**	**1820.1**	**4433.3**	**112340**						

Next, a forecasted intersectoral balance of the Russian economy until 2030 is formed. Initial data are: forecast of final demand for goods and services of industries (vector Y), forecast of gross output of various sectors of the economy (vector X). For railway transport, the revenue part is formed mainly as a result of cargo transportation. Therefore, the main conclusion on the basis of the ISB model will be as follows: to assess how much the volume of intermediate use of rail services in consumer sectors will change in 2030 compared to 2016. Calculations based on the ISB model allowed us to justify the forecast index of the physical volume of rail services (in all directions of transportation), which will be 1.5 (an increase of 50% by 2030 compared to the base year 2016).

In our opinion, forecasting based on the ISB or input-output models has a deep objective basis. For infrastructure industries, whose services are not final but intermediate, intersectoral proportions and relationships are the primary base for forecasting. The macroeconomic dynamics in general and in the separate sectors allows us to best predict the changing situation in the infrastructure sectors of the economy.

Table 5. Part 1 - Forecast of the intersectoral balance of goods and services in the Russian Federation in 2030, billion rubles (fragment), in comparable prices for 2016.

Consumer industries / supplier industries	timber	coal, peat	Iron ore	other mining products	oils and fats	flour and cereal production	beverages	lumber	other mining products	plywood, wood boards	pulp, paper, cardboard	coke
timber	35.69	0.27	0.01	0.04	0.06	0.00	0.02	0.51	83.81	48.51	45.24	0.00
coal, peat	0.19	192.52	0.12	1.19	1.02	0.42	0.31	0.17	0.50	0.07	6.68	77.14
iron ore	0.00	0.17	3.37	0.26	1.10	0.00	0.00	0.00	0.00	0.00	0.00	2.26
non-ferrous metal ore	0.01	0.01	0.33	3.97	0.26	0.00	0.00	0.00	0.01	0.00	0.00	0.10
other mining products	0.44	1.32	1.82	0.31	18.95	0.73	0.86	0.24	0.13	0.19	0.57	0.05
oils and fats	0.02	0.01	0.00	0.00	0.00	133	22.18	0.53	0.01	0.00	0.00	0.00
flour and cereal production	0.07	0.01	0.00	0.00	0.02	3.44	9.13	3.35	0.02	0.11	0.42	0.00
beverages	0.01	0.01	0.00	0.00	0.01	0.07	0.05	86.50	0.00	0.00	0.00	0.00
lumber	1.61	0.70	0.10	0.04	0.27	0.09	0.12	0.10	25.18	4.51	7.30	0.01
plywood, wood boards	0.24	0.10	0.00	0.02	0.13	0.00	0.00	0.02	1.05	11.60	0.04	0.00
pulp, paper, cardboard	1.17	0.10	0.03	0.03	0.66	0.86	0.44	4.06	0.67	15.67	66.13	0.00
coke	0.01	0.04	2.06	0.16	0.90	0.00	0.05	0.00	0.02	1.19	0.01	0.60
oil products	44.66	70.03	17.78	12.42	79.59	3.02	4.90	5.45	17.72	5.16	16.82	0.37
chemical substances	1.33	1.36	1.73	2.54	2.65	8.98	4.18	24.70	2.42	36.09	29.33	0.94
other chemicals	0.18	1.04	0.57	0.30	1.90	1.98	0.73	5.33	2.62	5.01	1.18	0.08
glass and products	0.04	0.06	0.01	0.01	0.20	0.48	0.07	64.46	0.23	0.19	0.03	0.00
refractories, non-refractory ceramics	0.08	0.10	0.08	0.08	0.88	0.01	0.02	0.04	0.01	0.01	0.01	0.21
...	…	…	…	…	…	…	…	…	…	…	…	…
wholesale	18.99	39.24	8.45	6.65	28.31	53.15	56.70	91.79	45.75	34.84	57.16	12.18
railway transport services	**12.27**	**51.97**	**20.32**	**2.61**	**34.42**	**10.58**	**5.74**	**15.44**	**11.13**	**5.84**	**12.72**	**22.78**
auxiliary and additional transport	8.94	45.31	15.70	1.90	35.20	10.29	10.49	14.98	7.93	3.61	9.90	5.34

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services												
other industries	78.80	269.78	115	46.74	283	450	311	426.06	63.24	64.47	168	11.76
Gross value added	**251.2**	**837.2**	**487.3**	**174.7**	**746.6**	**259.9**	**180.2**	**555.3**	**164.1**	**164.3**	**464.6**	**12.9**
Total resources at basic prices (gross output)	**479.1**	**1530.2**	**692.1**	**269.5**	**1277**	**939.4**	**610.3**	**1307.3**	**432.2**	**404.8**	**910.3**	**149.8**

Table 6. Part 2 - Forecast of the intersectoral balance of goods and services in the Russian Federation in 2030, billion rubles (fragment), in comparable prices for 2016 (Source: prepared by the authors).

Consumer industries / supplier industries	oil products	chemical substances	other chemicals	glass and products	…	wholesale	railway transport services	auxiliary and additional transport services	other industries	**Total intermediate consumption in industries**	**Total final use (final demand)**	**Total use (gross output)**
timber	0.00	1.80	0.04	0.00	…	0.41	**1.07**	0.63	60.46	280.89	198.22	479.1
coal, peat	0.04	17.47	3.99	0.03	…	16.67	**3.50**	3.55	293.00	913.83	616.35	1530.20
iron ore	0.00	8.04	2.05	0.00	…	0.00	**0.48**	0.46	7.47	512.95	179.11	692.1
non-ferrous metal ore	0.06	11.35	0.26	0.03	…	0.00	**0.08**	0.22	3.39	215.45	54.07	269.5
other mining products	1.47	120	4.87	10.39	…	2.43	**1.35**	19.28	278.85	617.92	659.52	1277.4
oils and fats	0.00	0.08	0.22	0.00	…	3.70	**0.29**	0.52	197.34	358.01	581.35	939.4
flour and cereal production	0.01	0.12	0.02	0.21	…	0.76	**0.12**	2.21	209.34	229.94	380.38	610.3
beverages	0.02	2.14	0.28	0.00	…	0.40	**0.04**	1.29	47.29	138.99	1168.32	1307.3
lumber	0.01	1.26	0.22	1.23	…	1.28	**3.66**	7.28	70.67	140.27	291.94	432.2
plywood, wood boards	0.02	0.14	0.00	0.02	…	1.43	**0.02**	0.53	210.51	231.75	173.07	404.8
pulp, paper, cardboard	0.36	2.45	1.09	0.32	…	13.72	**0.88**	4.52	314.61	453.96	456.34	910.3
coke	3.14	11.62	1.41	1.07	…	0.53	**0.15**	0.19	10.90	203.33	-53.51	149.8
oil products	1241	739	41.07	4.26	…	86.32	**80.07**	289	2518.03	5612.05	4670.59	10282.6
chemical substances	102	554	74.07	27.88	…	9.04	**1.05**	5.40	1153.50	2317.30	3482.51	5799.8
other chemicals	57.05	66.00	36.87	0.93	…	12.62	**1.39**	4.12	225.33	510.11	328.25	838.4
glass and products	0.03	1.11	0.16	26.88	…	1.42	**0.49**	0.55	110.85	284.00	69.36	353.4
refractories, non-refractory ceramics	0.06	1.56	0.27	3.21	…	0.30	**0.24**	0.60	53.87	154.49	41.74	196.2

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...	…	…	…	…	…	…	**…**	…	…	…	…	…
wholesale	230	273	35.43	18.96	…	608.30	**30.58**	87.58	5528.41	8846.08	13544.80	22390.9
railway transport services	**143**	**122**	**7.84**	**7.17**	**…**	**288.10**	**103**	**682**	**543.56**	**2555.31**	**99.37**	**2654.7**
auxiliary and additional transport services	403	130	6.77	5.41	…	793.70	**128**	563	1332.93	3744.13	2661.63	6405.8
other industries	5047	1082	97.81	85.42	…	5598.57	**675**	1709	45577.13	67778	97260.88	165039
Gross value added	**3029**	**2566**	**512.0**	**150.1**	…	**14808.6**	**1378**	**2787**	**100739.9**	**145028**		
Total resources at basic prices (gross output)	**10283**	**5800**	**838.4**	**353.4**	**…**	**22390.9**	**2655**	**6406**	**165038.8**			

Undoubtedly, the national model of the ISB cannot be used as the only one, but it must be supplemented by intersectoral interregional balances, taking into account the change in the cargo base in different regions, as well as the volumes of transit cargo.

Despite the clear advantage and positive characteristics of the applied approach to forecasting based on the ISB, we assess the following risks and limitations in its application. They are the problems of developing this methodological approach to forecasting the demand for freight rail transportation, and this study is aimed at solving them.

First. The parameters of the upcoming structural changes in the national and international commodity markets, taking into account the dynamics of structural changes, should be built into the ISB model.

Second. The model should take into account changes in the structure of the transport market by mode of transport. This is due to changing interspecific competition. The client needs door-to-door transportation at the best price and time. It is the parameters that reflect the competition of individual modes of transport in multimodal transport that will determine the quality of the forecast model. For example, large-scale investment projects in the field of road and pipeline transport can lead to a significant reduction in the volume of cargo transported by rail in certain directions, and the development of high-speed rail in the field of passenger transport can lead to a decrease in the volume of air transport.

Third. The model should take into account the emergence of new trade and transport routes. For example, changes in international trade are already evident in the growing volume of rail transport from China to the EU, and according to expert estimates [5], this trend is expected to intensify in the medium term and continue in the long term. In the near future, new solutions are expected for trade routes, including new services and transport infrastructure.

Fourth. Accounting parameters should be introduced in the source information base of such an important factor as advanced digital technologies. Digital solutions affect business processes and models, and their use is caused by changes in consumer behavior, accessibility of technologies and economic effect. The intersectoral proportions will be affected by the revision of existing and development of new services, products, business models, including mobile solutions, business architecture, digitalization of functions, managerial, transactional, internal and main transport and logistics processes.

It is obvious that in the long term, a revision of the industry and species statistical classification is possible due to the development of basic digital competencies in the field of innovation, data, system interaction, specialists with knowledge in digital technologies, digital culture, partner networks, digital tools and resources. Along with traditional, the role of new activities, such as, for example, intelligent transport systems, will help to optimize and increase the efficiency of transport networks.

The structure of the demand for educational services will also change in the ISB matrices. Due to the robotization of business processes, it is possible to solve the problem of a shortage of specialists, improve quality by expediting the procedures for tracking, calculating and managing claims.

It is obvious that there will be changes in the ratio of value added to output of industries, since new business models, types of digital operations, marketplaces and services, expanded interaction with customers through digital channels will become new sources of income that did not exist before. There will be new markets for goods and services, such as, for example, markets for unmanned vehicles.

In connection with the digital transformation of transport, the imminent arrival of technologies based on artificial intelligence is expected. For example, the use of unmanned vehicles for delivery. Such solutions will increase efficiency and reduce the time of delivery of commercial goods by eliminating the need for downtime, increasing the speed of delivery of goods.

Fifth. Parameters for strengthening the role of new markets should be built in the forecast period (Internet of things, robots, industry 4.0). Here, the ISB model will be subject to revision due to the trends of the growing online commerce market and optimization of the transport and logistics industry based on distributed registry and blockchain technologies. On this basis, the economy of joint consumption will develop, and the processes of integrating value chains between companies will intensify.

4. Discussion of the results

Macroeconomic modeling of the spatial flows of goods and people has become the basis for the design of transport systems since the mid-nineteenth century (for example, Carey, 1859) [8]. Since then, many model approaches have been developed to assess the demand for regional, state and interstate transportation. For a sufficiently long period, forecasts were based on qualitative and quantitative methods, which are based on extrapolation. Its modifications in more complex methods of time series, reflecting the seasonality of transportation, the cyclical development of industry markets, in particular, the Holt-Winters model, taking into account the multiplicative trend and seasonality, allowed improving the quality of transportation forecast for a certain decision-making period [9]. However, even econometric (multidimensional) models widely used at the end of the twentieth century could not provide a sufficient depth of design solutions for the development of the transport network, in particular in Russia [10].

Recently, most often for the purpose of spatial distribution, developers use entropy and gravity models built on the laws of physics. Many of the essential characteristics of the behavior of the seller and consumer of a product or service are conditionally assigned in these models on the basis of some weighted average expert opinions, which in some studies (in particular Deardorff, 1998) is recognized as a significant drawback [11]. In our case, this limitation of gravitational models - the impossibility of taking into account the individual preferences of the client in the transportation market will not allow reliably estimating the demand for transportation, based on the “values” of the transport service formed by the new technological structure. At the same time, the need for an accurate forecast for cargo and passenger flows is becoming an urgent task of state transport strategies and the transport business. The biggest problem is the forecasts of demand for freight transportation. In particular, a comprehensive study performed in the USA by NCHRP (The National Cooperative Highway Research Program) of traditional models for forecasting demand for transportation from the standpoint of their features, advantages, limitations and suitability for use should be noted [12]. Similar studies are underway in the European Community. In particular, in the study of the European Commission, 2014, which presents an analysis of the demand for all types of transport and multimodal transport, recommendations are given on the use of transport models for the organization of transportation by electric traction. [13]

Since our study includes not only demand modeling but also the transportation planning simulation itself, studies that describe the level of accuracy of models, in particular, an iterative modeling approach within the minimum size of the study area, the results of which are acceptable for the target territory, were significant for us (Bao, etc., 2014) [14] as well as the practice of using consumer demand models (dynamic) to predict the share of demand among alternative modes of transport. (Th. Tsekeris, Ch. Tsekeris, 2011) [15], analysis of the use of quantitative modeling methods (statistical, time series, econometric, artificial neural networks, and fuzzy methods) in choosing the most suitable planning and organization solution for multimodal transport using various modes of transport (Profillidis, Botzoris, 2018) [16].

The directions of future research in the field of simulation of demand for transportation are related to the use of demand models for transportation based on neural networks with the ability to display a nonlinear function of variables that describe the behavior of objects and subjects of the transport market. In the review (Pamula, 2016) [17] it is shown that multilayer neural networks of direct connection configurations are most often used in the study of transport.

The development of our study in the direction of modeling demand for high-speed transportation corresponds to new developments in the modeling of spatial transportation by Chinese specialists (Cao, etc., 2019) [18], which use the P-space resource to simulate (PSpice is part of the Design Center, DesignLab, OrCad-9 packages). This made it possible to include the parameters of the structural and spatial characteristics of the Chinese high-speed rail (CHSRN) at the level of railway junctions and the covered transportation network in the modeling. The spatial heterogeneity and hierarchical properties of CHSRN are considered in terms of train traffic intensity.

5. Conclusion

Forecasting the development of rail transportation should certainly be carried out using the considered approaches. This will significantly improve the quality of developed forecasts, take into account promising indicators and development trends of the global and national economies, individual regions and key consumer industries.

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