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Development of Business Intelligence in Transport Management

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ABSTRACT

Development of business intelligence is an important area of efficiency growth when solving urgent issues of improving transport management processes. The business intelligence is a source of objective and clear information necessary for management to make decisions. This is particularly pertinent when business intelligence is applied in railway transport for comparative analysis of contribution of regional and local divisions and units to the overall activity of railway infrastructure or operation company. In Russia, in the case of JSC Russian Railways there is a great need for assessment of the efficiency of regional corporate management centers whose responsibility is to coordinate activity within the boundaries of railways which are branches of the company.

The objective of the article is to present new methodological and practical aspects of designing and development of business intelligence tools for the process of economic assessment of share contribution of each railway (considered as a set of structural units within the regional corporate management center) to the results of the activity of JSC Russian Railways.

The research while developing and justifying the proposed methodological apparatus used tools for system analysis, methods of decomposition and synthesis, methodology of economic and mathematical modelling, fundamentals of information design theory, as well as methods of factor analysis.

As a result, within the framework of improving the business analytics apparatus for complex economic processes as applied to transport management systems, the paper suggests a methodological apparatus for development of multi-stage factor analysis (MFA) based on application of the hierarchical construction principle and the provisions of the root cause analysis (RCA) methodology, comprising integrated mechanisms for visualizing the results of analytical work by shaping chains of information panels, combined into tree structures, according to the principles of building mind maps. The suggested methodological apparatus approved by the considered case may also be applied to a wide range of similar problems in other modes of transport, multimode and combined transportation.

Keywords: *transport, transport management, management, railways, economic models, key performance indicators, factor analysis, business intelligence, business analytics, information panels, mind maps.*

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Introduction. During the era of digital economy development of information systems for decision-making support becomes a key aspect for the corporate efforts to ensure their high market competitiveness [1, pp. 1–28].

Decision support systems comprise among the most important components the tools of business analytics [1, pp. 210–240; 2, pp. 2–67], which serve as a source of management for comprehensive, exhaustive, objective and descriptive information required for making timely and effective management decisions.

Studying the accumulated international practices and current trends in development of theory and practice of business analytics [1–5] allows us to conclude that the key to its effectiveness is associated with the design and subsequent continuous development of the following closely integrated mechanisms:

• collection, processing of data and development of specialized indicators characterizing the activities of the company, its competitors and market conditions;

• creation of economic, mathematical and statistical models, as well as algorithms for their use for analysis and forecasting in order to identify key priorities in solving managerial problems;

• development of a visual interface for convenient interaction of a manager with source data, indicators used, model settings, as well as with mechanisms of visualization of the results of modelling and analysis in a form convenient for making managerial decisions considering the specifics of the business process under study.

According to international experts, [6, pp. 1–6], the intensification of development of business intelligence and analytics is the most promising driver of market growth in the current market conditions for transport companies.

Therefore, it is extremely important and urgent to continue to improve the apparatus of business intelligence in transport management systems.

Objective. *The objective* of the article is to present new methodological aspects of improving analytical tools focused on the study of complex economic processes in the field of railway transport management, with consideration of the practical aspect in relation to development of business analytics of the process of economic assessment of complex performance indicators (hereinafter CPI) of regional corporate management centers of JSC Russian Railways (hereinafter RCMC). The suggested methodology can be readily adapted to features of solving similar problems in other companies.

Results.

Influence of the specifics of CPI of comparative share contribution of RCMC on development of business intelligence

To ensure an increase in the efficiency of mechanisms for managing regional structures of JSC Russian Railways based on the territorial principle (level of heads (superior managers) of railways, branches of JSC Russian Railways) VNIIZhT employees continuously work on design and development of a CPI methodology based on economic assessments of the comparative share contribution (hereinafter referred to as CSC[1]) of regional corporate management centers into the results of the integrated work of JSC Russian Railways.

The key stages in development of methodology of complex performance indicators of comparative share contribution of regional corporate management centers (hereinafter referred to as CPI CSC RCMC methodology), the list of guidelines approved by JSC Russian Railways that characterize its relevance, as well as the current state of the calculation apparatus, are considered in detail in [7, pp. 107–114; 8, pp. 182–190].

In accordance with management tasks to be solved, the current CPI CSC system is a complex, interconnected complex of special calculation algorithms [8, pp. 184–185], allowing to evaluate:

• variable part of share contribution, determined on the basis of quarterly processing and aggregation of various cost above-target values of the total network in various analytical sections (freight transportation, passenger transportation, other activities, etc.) with their subsequent distribution based on specific indices;

[1] The term comparative share contribution used by the author in its original meaning does not refer to any legal aspect concerning liability or shares of joint stock company, etc., and denominates only managerial aspects of assessment of intra-corporate contribution of regional centres into overall activity and efficiency of the company as will be described further in the text. – *ed.note.*

• a fixed part of share contribution, formed on the basis of annual determination of the cost above-target values of the total network for various components (with their subsequent distribution on the basis of various indices);

• specific part of share contribution, determined on the basis of quarterly aggregation and comparative assessment of performance and cost indicators;

• total share contribution calculated quarterly (based on fixed, variable and specific parts) using weighting coefficients to ensure the balance of the system in terms of achieving management goals and objectives, as well as applying (if necessary) mechanisms for correcting share values by adjusting them to the upper / lower threshold.

To develop effective managerial decisions, the business intelligence toolkit of CPI CSC should provide management with convenient access to comprehensive information about key factors that determined the dynamics of CSC values of each RCMC as a result of the existing ratios of planned and current values for the current and past (base) calculation periods.

The presence in CPI CSC system of many different algorithms, each of which implies implementation of multi-stage calculations [8, pp. 185–190], with subsequent aggregation of all the results for determining the total share contribution for each RCMC, largely determines the need to use the concept of hierarchical analysis in the framework of root cause analysis (RCA) methodology [9, pp. 35–54], which has proven itself in analytics of complex, interconnected dependency models for railway transport management [10–13].

One of the most important aspects of achieving high efficiency and effectiveness in making managerial decisions is to ensure, within the framework of a single information window, maximum availability and visibility of the information required by management and analysts [5, pp. 1–6; 14, pp. 71–72;], which requires construction of complex mechanisms for visualizing the process and the results of calculating estimates of influence of factors based on the use of modern principles of infographic panels (a detailed description of which is given, for example, in [11, pp. 38–147].

It is advisable to carry out the combination and grouping of information panels within the framework of a specialized interface based on the methodology of constructing mind maps, which is one of the most convenient tools for structural analysis for analytical perception with respect to large-dimensional data [16, pp. 53–60].

Thus, the business analytics toolkit, based on the tasks to be solved and the specifics of constructing CPI CSC RCMC calculation system, is formed on the basis of the use of the multi-stage factor analysis (MFA), the results of which are presented in the form of information panels built on the basis of a tree-like hierarchical structuring and ranking of factors according to the force of their influence on the dynamics of the analyzed value (Pic. 1) from the level of total aggregated values through all intermediate stages of calculations (RCA principle «5 why») to the level of indivisible indicators (for example, the official figures reporting), for which further division into components is already impractical from the point of view of solving management tasks.

MFA methodology and mechanisms for visualizing its results using an example of business analysis of the process of evaluating the work of a region based on CPI CSC

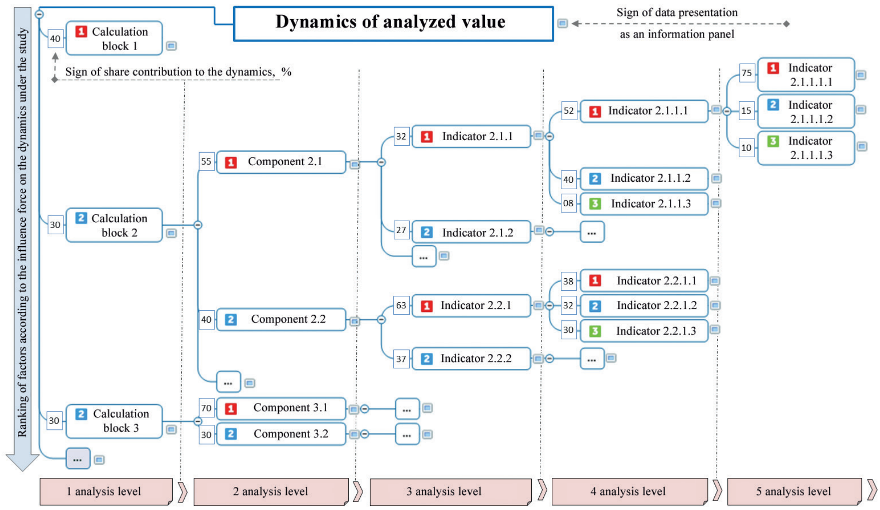
The proposed MFA methodology implies formation of a «core» of analytical algorithms with subsequent phased construction of hierarchical chains of specialized types of information panels for visual and convenient presentation of the necessary information:

• on the magnitude and dynamics of key values, as well as on the results of assessment (by the algorithms of the «basic core») of the comparative strength of influence of the studied factors within the framework of the studied model;

• on auxiliary analytical metrics for detailing various aspects of factor influence, including reflection of values and dynamics for initial indivisible (for a specific level of analysis) values.

The «core» of analytical algorithms, considering the specifics of constructing CPI CSC RCMC calculation system, is based on a combination of three methods of factor analysis: share contribution; chain substitutions; averaging the influence over the exhaustive search of permutations of parameters in the model (also called the method of weighted finite difference [17, p. 38]).

In more detail, the proposed approaches to formation of MFA «core» and its visualization



Pic. 1. The scheme of multistage factor analysis using information panels in the framework of a hierarchical tree-structured and ranking of factors according to the strength of influence.

Change in the first Quarter 2017 as compared to the fourth Quarter 2016	Above-target profits (freight transportation)			Above-target profit (other activity)			Total				
	fixed part	variable part	sum	fixed part	variable part	sum	fixed part	specific part	variable part	adjustment to lower limit	sum
1 OCT	0,06%	-0,46%	-0,40%	0,34%	0,15%	0,48%	-0,99%	0,00%	-0,76%	0,03%	**-1,72%**
2 KLG	0,01%	0,09%	0,10%	0,03%	0,10%	0,13%	0,03%	0,00%	0,19%	-0,22%	**0,00%**
3 MSK	0,15%	-0,65%	-0,50%	0,88%	-0,61%	0,27%	-0,07%	0,00%	-1,14%	0,03%	**-1,18%**
15 ZAB	0,23%	0,33%	0,57%	0,09%	0,08%	0,18%	0,18%	0,08%	0,44%	0,02%	**0,71%**
16 DVS	0,14%	0,00%	0,14%	0,25%	0,15%	0,39%	0,23%	0,03%	0,16%	0,01%	**0,43%**
Total	2,50%	-0,50%	**2,00%**	3,84%	0,39%	**4,23%**	0,00%	0,00%	0,00%	0,00%	**0,00%**
∑|Δ%|/railway (branch)	0,16%	0,27%	0,33%	0,25%	0,11%	0,27%	0,24%	0,08%	0,39%	0,03%	0,53%

Pic. 2. A fragment of the main information panel of the 1st stage of MFA for assessing the dynamics of CSC in the context of all components (hereinafter in the tables all the figures presented are conditional as well as their belonging to railways, and are not based on real data; abbreviations like OCT, KLG, MSK, ZAB, DVS, etc. mean names of 16 railways – branches of JSC Russian Railways).

will be considered directly at the example of constructing a basic chain of key types of supporting information panels used in business analytics of the process of quarterly comprehensive assessment of the dynamics of the region of responsibility of a railway (railway region). It is worth noting that, based on the tasks being solved and the observed results, the number, type and sequence of information panels in the analytical chain can vary significantly, and the article does not set out to present their complete list, which currently includes 26 various types based on the levels of the hierarchy.

One of the important tasks to be solved within the framework of CPI business analytics using MFA method is to identify key factors that determine (in the general calculation model) changes in the aggregate indicator of CSC (used, inter alia, in distribution of the incentive payments to employees by the head of a railway [8, p. 182]), for the purpose of developing managerial decisions aimed at eliminating «bottlenecks» that did not allow (in the observed period) to achieve the necessary CSC dynamics required by the management.

Given the complex nature of calculations with the presence of many different interlinked algorithms, the search chain for key factors, as a rule, begins (the first step in detailing MFA) with the study of data of the main information panel of the dynamics of changes in CSC in the context of all components (Pic. 2).

It is important to note that the format of the article does not allow to fully reflect all the interactive solutions implemented in the information panel. So, for the information panel (Pic. 2), it is provided that when you hover the mouse over the cell of the info panel, the initial values of the studied quarters are

Change in the fixed part	Fixed part of contribution to above-target profits (freight transportation)			Fixed part of contribution to above-target profits (other activity)			Fixed part of contribution to cost saving, excl. depriciation			Total value of the fixed part		
	12m2016	**12m2017**	+/-	**12m2016**	**12m2017**	+/-	**12m2016**	**12m2017**	+/-	**12m2016**	**12m2017**	+/-
1 OCT	3,92%	3,98%	0,06%	1,17%	1,51%	0,34%	0,00%	0,00%	0,00%	8,11%	7,13%	-0,99%
16 DVS	4,40%	4,54%	0,14%	0,97%	1,22%	0,25%	0,00%	0,00%	0,00%	5,67%	5,91%	0,23%
Total	**52,82%**	**55,32%**	**2,50%**	**13,82%**	**17,66%**	**3,84%**	**0,00%**	**0,00%**	**0,00%**	**80,00%**	**80,00%**	**0,00%**
∑|Δ%|/railway (branch)			0,16%	–	–	0,25%	–	–	0,00%	–	–	0,24%

Pic. 3. A fragment of one of the auxiliary information panels of the 1st stage of MFA (conditional figures are presented; abbreviation 12m15 means a given period (e.g. 12 months of 2015, etc.).

shown in a pop-up window, and when you right-click on the cell, you can add a text note or select another type of information panel that includes values of this cell (for example, the information panel shown in Pic. 3).

The values of the observed dynamics presented in the information panels at the level of individual RCMC and for the whole network (in the context of all components of the total index) are determined based on the use of factor analysis by share participation method [17, p. 39], according to the formula:

$$\Delta_{\chi\_i} = \alpha_{\chi\_i} - \alpha_{\chi\_i}^{base}, \qquad (1)$$

where α_{χ_i}, $\alpha_{\chi\_i}^{base}$ are respectively the current (studied) and basic (selected as the basis for comparison) values of the share contribution (in percent) for the i-th RCMC obtained using the χ-type calculation algorithm (described in detail in [8, pp. 185–190]) determined by the type of calculated part (fixed, variable, specific, corrective) and the type of activity (freight transportation, passenger transportation, other activities).

An analysis of each of the first 16 lines of the information panel (Pic. 2), using the «heatmap» visualization technique, allows to visually see what has contributed to the change in the total fractional index observed on a particular railway, and also to understand what type of calculated part and type of activity has shown the greatest impact.

The row of results, in turn, reflects redistribution of cumulative influence within the total contribution of specific activities and in the context of the types of calculation used.

In addition, in the framework of the information panel of the dynamics of changes in CSC, to compare the strength of influence of χ types of calculation algorithms on the observed level of variability of the railway contribution, the analytical metric «Average value of the observed changes per railway» (the last row of the information panel), determined by the formula, is used:

$$v_{\chi} = \frac{\sum_{i=1}^{16} \left|\Delta_{\chi\_i}\right|}{16}, \qquad (2)$$

where Δ_{χ_i} are values of the observed dynamics of the i-th RCMC, obtained based on the application of the χ-th type of calculation algorithm.

It should be noted that at the final stage of share calculations [7, pp. 107–114; 8, pp. 185–190] for each of the studied activities, a universal model of four elements is used:

- the selected integral «distribution meter» for railways (which has a direct impact on achievement of above-target financial values and is most suitable for comparing activities within the framework of solving specific management tasks);
- sum of the integral «distribution meter» for all railways;
- above-target financial value for distribution received by all railways;
- total share contribution index, aggregating all generated above-target financial values.

Therefore, at the second stage of MFA that provides detailing by the selected types of activity (which had the strongest influence on the dynamics of the total share contribution), a search is made for key factors of influence based on the use of the chain substitution method (the general mechanism of which is described in [17, pp. 33–34]; and its various aspects for solving practical problems of railway transport are described in [13, pp. 51–59; 18, pp. 41–178; 19, pp. 254–262]).

For a fixed and variable calculated parts for each of the types of activities, the comparable share influence of the studied factors is determined by the solution of the system of equations:

$$
\begin{aligned}
&S_{a_{ji}}^{\psi_z} = 100\ \% \left(\Delta\Phi_{a_{ji}}^{\psi_z} / \sum_{z=1}^{4} \Delta\Phi_{a_{ji}}^{\psi_z} \right); \\
&\Delta v_{a_{ji}} = \sum_{z=1}^{4} \Delta\Phi_{a_{ji}}^{\psi_z} = \\
&= k_{ja} y_{ja} \begin{pmatrix} \left(u_{oia} / \sum_{i=1}^{16} u_{oia} \right) \left(S_{oja} / v_{oa} \right) - \\ - \left(u_{hia} / \sum_{i=1}^{16} u_{hia} \right) \left(S_{hj} / v_{ha} \right) \end{pmatrix}; \\
&\Delta\Phi_{a_{ji}}^{\psi_1} = k_{ja} y_{ja} \left(\left(u_{hia} - u_{oia} \right) / \sum_{i=1}^{16} u_{hia} \right) \left(S_{hja} / v_{ha} \right); \\
&\Delta\Phi_{a_{ji}}^{\psi_2} = k_{ja} y_{ja} u_{oia} \left(1 / \sum_{i=1}^{16} u_{oia} - 1 / \sum_{i=1}^{16} u_{hia} \right) \left(S_{hja} / v_{ha} \right); \\
&\Delta\Phi_{a_{ji}}^{\psi_3} = k_{ja} y_{ja} \left(u_{oia} / \sum_{i=1}^{16} u_{oia} \right) \left(\left(S_{oja} - S_{hja} \right) / v_{ha} \right); \\
&\Delta\Phi_{a_{ji}}^{\psi_4} = k_{ja} y_{ja} \left(u_{oia} / \sum_{i=1}^{16} u_{oia} \right) S_{oja} \left(1 / v_{oa} - 1 / v_{ha} \right),
\end{aligned}
\tag{3}
$$

where a is the type of part of share contribution (fixed or variable);

y_{ja} is the weighting coefficient, providing a balanced influence of the analyzed a-part of the railway's share contribution on the total index from the point of view of fulfilling motivation tasks [8, p. 188];

k_{ja} is the weighting coefficient for the j-th activity when calculating the total index in the framework of the a-th part of the share contribution;

$\Delta v_{a_{ji}}$ are observed changes in the total index of share contribution in the framework of its a-th part for the j-th type of activity on the i-th railway;

$\Delta\Phi_{a_{ji}}^{\psi}$ is the influence of the factor ψ on the change of $\Delta v_{a_{ji}}$ when comparing the initial *(h)* and final *(o)* calculation conditions;

ψ_1 is the dynamics factor of the used distribution meter *(u)* on the i-th railway;

ψ_2 is the dynamics factor of the total value of the distribution meter for all railways;

ψ_3 is the dynamics factor of the distributed above-target financial value *(S);*

ψ_4 is the dynamics factor of the total share contribution index *(v)*;

$S_{a_{ji}}^{\psi_z}$ is the value reflecting the share of the influence of the z-th factor ψ on variability of $\Delta v_{a_{ji}}$.

The use of the method of chain substitutions at this stage of factor analysis is justified by the fact that using the dynamics of the total share contribution index as the last studied factor allows us to reflect in it (through an indecomposable remainder) the influence of interaction of other factors, which fully corresponds to the methodological essence of the total railway contribution index, which is an integral indicator for assessing comparative performance of activities [7, pp. 106–108; 8, pp. 184–186].

The type of information panels used to visualize the results of the second stage of the MFA in the context of the fixed and variable parts of the calculation by type of activity is shown in Pic. 4.

For each of the railways, in columns 2–6 of the information panel for each of the first 16 rows (using the infographic «heatmap» method) areas of the influence of each of the four factors-elements on the dynamics of the share contribution are shown.

Columns 7–9 show the absolute values of the meters used in the analysis for the studied time sections (with visualization based on «histograms»), as well as an auxiliary analytical metric characterizing the rate of change.

A comparison (in the context of each row) of the values presented in the second and third columns (using, if necessary, the data of the last

Railway	Change of the variable part of contribution to the index	including due to changes in:				Amount of the above-target conditional profit of the railway, mln rub.		
		Amount of the above-target conditional profit of the railway (ΔA)	Amount of the above-target conditional profit of the network (∑ΔA)	Amount of the above-target profit from freight transportation (Sfr)	Total contribution index (I)	4th Q 2016	1st Q 2017	1st Q 17 / 4th 16
OCT	-0,46%	-0,582%	0,140%	-0,170%	0,149%	698,8	154,1	0,22
KLG	0,09%	0,034%	0,066%	-0,080%	0,070%	40,7	72,2	1,78
MSK	-0,65%	-0,650%	0,000%	0,000%	0,000%	608,3	0,0	0,00
GOR	0,45%	0,263%	0,223%	-0,272%	0,238%	0,0	245,5	–
NETWORK	-0,50%	-3,32%	3,32%	-4,04%	3,53%	6756,34	3651,21	0,54
Value of total contribution index (I), mln rub.:						11191,87	5307,72	0,47
Amount of above-target value in total index (0,1•0,7•Sfr), mln rub.:						808,57	356,69	0,44

Pic. 4. A fragment of the main information panel of the 2nd stage of MFA on the variable part of contribution from cargo transportation (conditional figures are presented).

Contribution to the total network index from:	Value, mln rub.		1st Q 2017 / 4th Q 2016	Share in the total contribution index (I), %		Change in contribution structure (1st Q 2017 / 4th Q 2016), %	Share of the 1st Q 2017 in the total contribution index of the 4th Q 2016, %	Contribution to the observed change in total contribution index, %
	4th Q 2016	1st Q 2017		4th Q 2016	1st Q 2017			
Sum of above-target profit from freight transportation (Sfr•0,7)	8085,7	3566,9	0,4	**72,2%**	**67,2%**	-5,0%	31,9%	-40,4%
Sum of above-target profit from passenger transportation (Spass•0,7)	692,2	389,8	0,6	**6,2%**	**7,3%**	1,2%	3,5%	-2,7%
Sum of above-target profit from other activities (Soth)	2414,0	1351,0	0,6	**21,6%**	**25,5%**	3,9%	12,1%	-9,5%
Total index (I)	**11191,9**	**5307,7**	**0,5**	**100,0%**	**100,0%**	–	**47,4%**	**-52,6%**

Pic. 5. An example of the main information panel of the 3rd stage of MFA for analysis of the total contribution index in its variable part (conditional figures are presented).

	4th Q 2016				1st Q 2017					1st Q 2017 / 4th Q 2016	1st Q 2017 / 4th Q 2016		
Railway	Planned, mln rub.	In fact, mln rub.	Above-target value, mln rub.	Above-target value, %	Planned, mln rub.	In fact, mln rub.	Above-target value, mln rub.	Above-target value, %	Contribution to change in above-target value as compared with 4th Q	Above-target value, %	Planned	In fact	Above-target value, mln rub.
OCT	28968,630	29911,268	942,638	8,16%	31302,484	31444,241	141,757	2,78%	-6,93%	-5,38%	1,08	1,05	0,15
KRS	18448,607	18908,997	460,390	3,99%	18679,695	19245,602	565,907	11,11%	0,91%	7,12%	1,01	1,02	1,23
VSB	16671,237	16927,973	256,736	2,22%	16436,707	17003,636	566,929	11,13%	2,69%	8,90%	0,99	1,00	2,21
ZAB	3292,149	3511,851	219,702	1,90%	3108,858	3284,797	175,939	3,45%	-0,38%	1,55%	0,94	0,94	0,80
DVS	27747,165	28540,188	793,023	6,87%	28947,873	29166,476	218,603	4,29%	-4,97%	-2,58%	1,04	1,02	0,28
Total	**326464,7**	**338015,73**	**11551,025**	**100,00%**	**339850,161**	**344945,7795**	**5095,619**	**100,00%**	**-55,89%**	**0,00%**	**1,04**	**1,02**	**0,44**

Pic. 6. A fragment of the main information panel of the 3rd stage of MFA for analysis of the amount of above-target profit in the variable part of the contribution from freight transportation (conditional figures are presented).

three columns), allows us to correlate the influence of the actions of a railway (characterized by the metrics used) on the total share contribution relative to the actions of other railways. Comparisons of each of the rows of the fourth and fifth columns show the revealed influence of the dynamics of above-target incomes for the studied type of activity relative to above-target values for other types of activity, which eventually formed the value of the total index.

At the third stage of detailed MFA according to the calculations of the fixed and variable parts of the share contribution, further branching of the analytical chain of information panels is carried out to identify key factors of influence of a lower hierarchy in the context of the studied element of the universal model (3).

The use of information panels of the analysis of the total index (Pic. 5) allows us to visually, based on the use of share participation mechanisms, compare the effect of changes in the sums of above-target values (by activity) on the dynamics of the total index.

The type of information panels shown in Pic. 6, graphically represents the process of formation of above-target values and makes it possible to compare the influence of the contribution of individual railways, evaluate the corresponding effect of the ratios on the rate of change of plan and actual data.

Analysis of influence of various indicators on the dynamics of the integral «distribution meter» begins with a study of the type of information panels shown in Pic. 7.

In this information panel (vertically divided into two parts representing the compared time sections, current and basic), three groups of calculation and analytical columns are selected that characterize the data in the context of railways.

In the first group (2–6 columns), based on share participation method, the influence of the planned values of each of the indicators on the integral value of the distribution meter is demonstrated. At the same time, changes in the share distribution of planned values (in the current time section compared to the base) are highlighted using the «two-color scale» infographic technique (as applied to the background of the cells).

In the second group (columns 7–11), separately for the base and current periods, based on identification of the ratio of actual values to the total figure of the plan, the contribution of each indicator to the observed changes in the distribution meter (with visualization of the changes in the form of two-color scales) is demonstrated.

Railway	Unloading planned, % in planned conditional profits	Loading planned, % in planned conditional profits	Paid empty run planned, % in planned conditional profits	Cargo turnover tariff received, planned, % in planned conditional profits	Conditional profits planned, %	Unloading in fact, % in planned conditional profits	Loading in fact, % in planned conditional profits	Paid empty run in fact, % in planned conditional profits	Cargo turnover tariff received, in fact, % in planned conditional profits	Conditional profits in fact, %	Conditional profit (in fact / planned), %	Above-target value, %
1st Q 2017												
OCT	0,80%	0,37%	1,89%	4,31%	7,37%	0,78%	0,38%	1,93%	4,34%	7,43%	0,06%	4,22%

DVS	0,52%	0,19%	2,35%	5,23%	8,28%	0,50%	0,19%	2,34%	5,22%	8,24%	-0,04%	0,00%
Network	**4,44%**	**4,99%**	**25,82%**	**64,76%**	**100,00%**	**4,45%**	**5,01%**	**26,31%**	**65,51%**	**101,28%**	**1,28%**	**100,00%**
4th Q 2016												
OCT	0,73%	0,38%	1,78%	4,12%	7,03%	0,76%	0,39%	1,85%	4,27%	7,28%	0,25%	10,34%

DVS	0,52%	0,20%	2,33%	5,24%	8,29%	0,50%	0,20%	2,30%	5,19%	8,19%	-0,10%	0,00%
Network	**4,51%**	**5,01%**	**26,14%**	**64,34%**	**100,00%**	**4,61%**	**5,12%**	**26,45%**	**66,18%**	**102,36%**	**2,36%**	**100,00%**

Pic. 7. A fragment of the main information panel of the 3rd stage of MFA for analysis of the influence of performance indicators in the variable part of the contribution from freight transportation (conditional figures are presented).

No.	Branch	Planned, mln rub.	In fact, mln rub.	Above-target value, mln rub.	Above-target value, %	Planned, mln rub.	In fact, mln rub.	Above-target value, mln rub.	Above-target value, %	Above-target value, %	Above-target value, absolute figures	Planned	In fact	Above-target value, mln rub.
1	CCC	5,28	7,01	1,73	0,07%	0,05	0,71	0,65	0,05%	-0,02%	-1,08	0,01	0,10	0,38

21	DCRE	0,26	0,27	0,02	0,00%	0,24	0,33	0,09	0,01%	0,01%	0,08	0,95	1,23	5,91
	Total for ZSB	**-285,99**	**-45,01**	**299,14**	**12,39%**	**-310,31**	**-187,45**	**122,86**	**9,09%**	-3,30%	-176,27	**1,09**	**4,16**	**0,41**
	NETWORK	**5670,21**	**7360,38**	**2413,99**	**100,00%**	**4189,56**	**5265,12**	**1351,02**	**100,00%**	-	**-1062,97**	**0,74**	**0,72**	**0,56**

Pic. 8. A fragment of the main information panel of the 4th stage of MFA for analysis of the amount of above-target profit from other activities as part of the calculation of the variable part (conditional figures are presented).

Year: 2016 2017 2018

Quarter: 1 2 3 4

Month: 7 8 9 10 11 12 / 1 2 3 4 5 6

Railway: OCT KLG MSK GOR SEV SKV UVS PRV KBSH SVR UUR ZSB KRS VSB ZAB DVS

Year	Quarter	Month	Railway	Σ Cargo turnover taking into account paid empty miles, mln t•km plan	Σ Cargo turnover taking into account paid empty miles, mln t•km in fact	Σ Cargo turnover tariff, mln tariff t•km plan	Σ Cargo turnover tariff, mln tariff t•km in fact	Σ Loaging absolute thous. ton plan	Σ Loaging absolute thous. ton in fact	Σ Unloaging cars average per day plan	Σ Unloaging cars average per day in fact	Fact/Plan-1: Cargo turnover taking into account paid empty miles	Fact/Plan-1: Cargo turnover tariff	Fact/Plan-1: Loading	Fact/Plan-1: Unloading
		8 AUG	1 OCT	20827	20890	16075	16156	11160	11160	10124	9901	0,3%	0,5%	0,0%	-2,2%
		9 SEP	1 OCT	20227	20429	15661	15896	10909	10440	10310	10032	1,0%	1,5%	-4,3%	-2,7%
	4	10 OCT	1 OCT	21084	21358	16383	16530	10599	9560	10173	9817	1,3%	0,9%	-9,8%	-3,5%
		11 NOV	1 OCT	20632	20570	15967	15727	9360	9360	9928	10037	-0,3%	-1,5%	0,0%	1,1%
		12 DEC	1 OCT	21121	21586	16313	16558	9779	9300	9833	9990	2,2%	1,5%	-4,9%	1,6%

Pic. 9. A fragment of an example of the main information panel of the 4th stage of MFA for analysis of the influence of performance indicators in the fixed and variable parts of the contribution from freight transportation (conditional figures are presented).

Railway	Change in the specific part of the contribution to the index (1st Q 2017 / 4th Q 2016)	including due to changes: within specific part based on performance, %	including due to changes: within specific part based on cost, %	Dynamics of specific indicators: Performance in 4th Q 2016 (mln of specific t•km/persons)	Performance in 1st Q 2017 (mln of specific t•km/persons)	Dynamics, %	Cost in 4th Q 2016 (rub./specific t•km)	Cost in 1st Q 2017 (rub./specific t•km)	Dynamics, %
OCT	0,00%	0,000%	0,000%	0,957	0,968	1,01	0,535	0,446	0,83

DVS	0,03%	0,025%	0,000%	1,352	1,362	1,01	0,442	0,408	0,92
NETWORK	**0,00%**	**0,00%**	**0,00%**						
			Median of network values	**1,271**	**1,266**	**1,00**	**0,358**	**0,321**	**0,896**
			Sum od network distributed delta values	**2,127**	**2,157**	**1,014**	**1,517**	**1,573**	**1,037**

Pic. 10. A fragment of the main information panel of the 2nd stage of MFA for analysis of the specific part of the share contribution (conditional figures are presented).

The third group (12–13 columns) reflects the contribution of railways to achievement of an above-target value (for the type of activity being studied), as well as deviations from the planned values for the distribution meter (in this case, a pairwise comparison of the cells of the first and second group of columns reveals the influence of the corresponding indicators).

At the fourth and subsequent stages of MFA, according to the calculations of the fixed and variable parts of the share contribution (if necessary), further detailing of the information used in the models is carried out, including both decomposition of indicators and reduction of aggregation levels of used data in order to identify key factors of influence of a lower hierarchical level (examples of information panels are given in Pic. 8 and 9).

It is important to note that the method of chain substitutions is used only at the second stage of MFA (in the analysis of a universal model of four elements), since the order of factors in lower-level models can no longer be unambiguously substantiated. Where it is impossible to apply the concept of the share participation method, the method of averaging the influence over the exhaustive search of permutations of parameters in the model is used. A clear explanation of the method and details of its practical use are described in [13, pp. 56–58] based on the solution of the following universal (for any type of model with any number of parameters) system of equations:

$$\begin{cases} S_{\Phi_i} = 100\ \% \left(\Delta F_{\Phi_i} \Big/ \sum_{v=1}^{z} \Delta F_{\Phi_v} \right); \\ \Delta F_{\Phi_i} = \left(\sum_{M=1}^{z} \sum_{w=1}^{(z-1)!} \Delta \Phi_M^{\text{var\_}w} \right) \Big/ (z!); \\ 1 < m < z; \\ \Delta \Phi_1^{\text{var\_}w} = f\left\{ \Phi_1^{o\_w}, ..., \Phi_{z-1}^{h\_w}, \Phi_z^{h\_w} \right\} - \\ - f\left\{ \Phi_1^{h\_w}, ..., \Phi_{z-1}^{h\_w}, \Phi_z^{h\_w} \right\}; \\ \Delta \Phi_m^{\text{var\_}w} = f\left\{ \Phi_1^{o\_w}, ..., \Phi_m^{o\_w}, \Phi_{m+1}^{h\_w}, ..., \Phi_z^{h\_w} \right\} - \\ - f\left\{ \Phi_1^{o\_w}, ..., \Phi_m^{h\_w}, ..., \Phi_z^{h\_w} \right\}; \\ \Delta \Phi_z^{\text{var\_}w} = f\left\{ \Phi_1^{o\_w}, ..., \Phi_{z-1}^{o\_w}, \Phi_z^{o\_w} \right\} - \\ - f\left\{ \Phi_1^{o\_w}, ..., \Phi_{z-1}^{o\_w}, \Phi_z^{h\_w} \right\}, \end{cases} \tag{4}$$

where S_{Φ_i} is the value reflecting the share of the influence of the i-th factor on variability of the resulting variable $\sum_{v=1}^{z} \Delta F_{\Phi_v}$ in comparison with the studied factors;

ΔF_{Φ_i} is the value characterizing (for comparison purposes) the absolute influence of the i-th factor in the studied model of the relationship, containing z factors, on the observed variability of the resulting variable;

$\Delta \Phi_M^w$ is assessment of influence (on the resulting variable) of the factor standing in the M-th place in the w-th version of the permutation of factors in the studied model;

$z! = 1 \cdot 2 \cdot 3 \cdot ... \cdot z$ is the factorial z, reflecting the total number of all possible variants of permutations of factors in the studied model of dependence;

$f\left\{ \Phi_1, ..., \Phi_{z-1}, \Phi_z \right\}$ is the value of the resulting variable, determined by the values of the factors $\Phi_1, ..., \Phi_{z-1}, \Phi_z$;

$\Phi_1^{o\_w}, \Phi_m^{o\_w}, \Phi_z^{o\_w}$ is the final value of the factors, standing, respectively, in the first, m-th and last places in the w-th version of the permutation of factors in the studied model;

$\Phi_1^{h\_w}, \Phi_m^{h\_w}, \Phi_z^{h\_w}$ is the initial value of the factors, standing, respectively, in the first, m-th and last place in the w-th version of the permutation of factors in the studied model.

The approaches used to form multi-stage visual-analytical chains and the corresponding design of MFA info panels within the specific and correcting calculation parts are similar to those described above (as part of the analysis by types of activity). So, for the second stage of MFA in information panels, the mechanisms of share participation are used together with an array of auxiliary digital and visual information (an example of the type of information panel used to analyze the specific part is presented in Pic. 10). For the subsequent stages of detailing, the influence of key factors is determined solely on the basis of the method of averaging the influence over a complete search of the permutations of parameters in the model (4).

Conclusion. As part of improving the business analytics apparatus for complex economic processes in transport management systems, a new methodological toolkit for hierarchical multi-stage factor analysis using analytical chains of information panels combined into tree structures according to the principles of building mind maps has been developed and justified.

The presented methodological approaches were successfully implemented in development of business analysis of the process of economic estimation of the comparative share contribution of the railways used to control and manage their activities, as well as calculating the bonus funds of the branches of JSC Russian Railways.

It is important and relevant to integrate the developed methodological mechanisms into the business analytics system of the production and economic model of the long-term development program of JSC Russian Railways.

The stated methodological approaches, without significant changes, can also be used to improve business analytics of economic processes in the management systems of sea, river, air and road transport.

The consistent development of the presented methodological tools, along with expansion of the scope of its use, should contribute to a further increase in the quality of managerial decisions and the efficiency of the transport system.

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