Formation of Hierarchical Strategies for Risk-Stable Transportation of Export Grain from Russian Federation Based on Expert Surveys

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Keywords: Export logistics, Systemic risks, Factors having different weight, Expert survey, Sequential preference procedure, Hierarchical strategies.

Abstract: The article discusses the problem of risk-stable management of grain export. Systemic risks are involved as the main factors in recording disruptions in the operation of the logistics system. The initial data for identifying and analyzing systemic risks are the results of expert surveys. To make the analysis, a modification of the Churchman-Ackoff sequential preference procedure for factors having different weight was constructed. The modification constitutes the scientific novelty of the work.

1 INTRODUCTION

Today, the transportation industry of agricultural products, and, in particular, export grain, is under significant risk associated with unprecedented pressure on the industry from the countries of the collective West. And it becomes problematic to make balanced and adequate management decisions, which ultimately affects the quality of transportation of export grain abroad. Understanding risk as the degree of uncertainty in the functioning of a management object in a situation where there is a possibility of deviation of the results of operation and, in general, the consequences of the implemented production activities, it is necessary to identify the risks of low efficiency of decision-making and/or high subjectivity of the results of the implementation of management decisions.

There are currently a number of methods used to identify and assess risks. The scenario method allows you to simulate possible future events and explore their degree of influence, as well as the expected consequences. A. S. Bichevina (Bichevina, 2021) notes that this method is suitable for use in situations of uncertainty. For innovative projects, the decision tree method is often used for identification and forecasting (Nakaryakova, Ruskaov, Ruskaova, 2020; Shorabeh, Samany, Minaei, 2022), and comprehensive analysis of project risks (Vasilyeva, Krupnov, 2020). The later method is often used to assess risk using machine learning. (Elhazmi, Al-Omari, Sallam, 2019).

2 COMPILATION OF A RISKS REGISTER

Instead of assessing the grain supplies risk disruption, we will put forward the provision of using the grain supply weight strategies as probabilistic parameters that complement risks, making a systematization of *route superfactors* of grain export routes (x). Correlating them with complex risks, we use the existing routes for RF grain exports:

- Azov-Black Sea (Africa, Asia) – x^{azov};
- Baltic (EU) – x^{balt};
- Caspian (Iran) – x^{iran};
- Far Eastern (South-East Asia) – x^{east};
- Central Asia (to Central Asia with export of surplus to India, etc.) – x^{asia}.

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We will express the elements of the implementation of these strategies as a set of the following components – logistics factors, with their *constituent subfactors* of transportation, correlating them, respectively, with basic and private risks:

- **grain sources** (x_1) – grain-producing regions, characterized by: regional price of a ton of wheat – x_{11}; maximum volumes of wheat sent for export – x_{12}; variety (soft / hard, analyzed for the future) – x_{13};
- **railway route** (x_2) – several railways, defined by: tariff for transportation of a ton of wheat per 1 km (including cargo insurance) – x_{21}; maximum throughput capacity of exported wheat – x_{22}; speed of movement to the selected point of shipment (port) – x_{23};
- **point of shipment** (x_3) – place of departure of grain abroad by sea, involving: tariff for storing a ton of wheat in spec. terminals – x_{31}; maximum wheat storage capacity – x_{32}; maximum period of stay in grain terminals before shipment – x_{33};
- **transshipment center** (x_4) – ports of arrival of grain for distribution, meaning: cost of transporting a ton of grain by sea per one nautical mile – x_{41}; coefficient of wheat loss during sea transportation – x_{42}; path length from the geographical center of the group of RF ports for the route –x_{43};
- **customer pool** (x_5) – one / several purchasing countries, described by: the selling price of a ton of grain in the markets of a countries group (including duties) – x_{51}; average time for unloading ships after arriving at their destination – x_{52}; volume of expenses for technical support of the vessel for the next grain voyage) – x_{53}.

For flexibility in the description of this multifactor system, the factors and subfactors of a particular route are marked with their determinant (azov, balt, iran, east, asia).

2 CONSTRUCTING TABLES OF SEQUENTIAL PREFERENCES

We will find the weights of the superfactors, factors and subfactors mentioned above from the survey system for the expert. It evaluates routes separately and with its components.

1. Create a chain of priorities for the components of the route, for example, x^{azov} is the best, x_5^{azov} is the worst, $x^{azov} \succ x_1^{azov} \succ x_2^{azov} \succ x_3^{azov} \succ x_4^{azov} \succ x_5^{azov}$, strategy, as a route superfactor, is in first place, then its parts are logistic factors.

2. Factor x^{azov} is assessed as 1 and other factors are given estimates relative to it.

3. We generate different combinations of components and look for their priority relative to individual components, for example, for the Azov-Black Sea direction (Table 1).

Counting is carried out for those combinations with the priority factor smaller than the sum of its components. We build the same tables for factors and subfactors $x_1^{azov} \succ x_{11}^{azov} \succ x_{12}^{azov} \succ x_{13}^{azov}$.

We do the same for routes with other determinants “balt, iran, east, asia”:

- each route superfactor – 5 surveys of the same type as in Table 1;
- each of the logistic factors – 25 surveys of the same type as in Table 2.

Further on, based on the sequential preference procedure, it is possible to determine both initial and adjusted weights together with the following determination of the risk degree.

If it is not possible to obtain expert judgments for logistics factors (experts are usually decision makers at agricultural enterprises) because of the large number of surveys, then the weights of transportation subfactors (75 positions in total) should be sought based on empirical considerations and practice of the influence of these components of transport strategies in the economy.

Some factors can be replaced with similar ones, but in a different quality, for example, cheap grain with expensive grain. After the replacement, the weights of the subfactors are recalculated.

Table 1: Scheme of pair wise comparison of superfactors and factors with their possible combinations.

x^{azov} or $x_1^{azov} + x_2^{azov} + x_3^{azov} + x_4^{azov} + x_5^{azov}$	x_1^{azov} or $x_2^{azov} + x_3^{azov} + x_4^{azov} + x_5^{azov}$	x_2^{azov} or $x_3^{azov} + x_4^{azov} + x_5^{azov}$
x^{azov} or $x_1^{azov} + x_2^{azov} + x_3^{azov} + x_4^{azov}$	x_1^{azov} or $x_2^{azov} + x_3^{azov} + x_4^{azov}$	x_2^{azov} or $x_3^{azov} + x_4^{azov}$
x^{azov} or $x_1^{azov} + x_2^{azov} + x_3^{azov}$	x_1^{azov} or $x_2^{azov} + x_3^{azov}$	x_3^{azov} or $x_4^{azov} + x_5^{azov}$

x^{azov} or $x_1^{azov} + x_2^{azov}$		

Table 2: Scheme of pair wise comparison of superfactors and the "Grain Sources" factor with their combinations.

x_1^{azov} or $x_{11}^{azov} + x_{12}^{azov} + x_{13}^{azov}$	x_{11}^{azov} or $x_{12}^{azov} + x_{13}^{azov}$
x_1^{azov} or $x_{11}^{azov} + x_{12}^{azov}$	

3 PROCESSING EXPERT OPINIONS

The estimates v^{azov}, v^{balt}, v^{iran}, v^{east}, v^{asia}. correspond to the superfactors x^{azov}, x^{balt}, x^{iran}, x^{east}, x^{asia}. Having received from table 1 comparison of superfactor and factor sets, we apply the Churchman-Ackoff procedure, where the signs "more priority" and "less priority" are arbitrary (as set by experts) and the priorities become in equations (1).

These opinions are processed using the Churchman-Ackoff procedure (into two steps).

Step 1. In equations (1) are replaced by equations and initial scores are sought, assigning the maximum score on the scale to the most influential factor.

Step 2. The estimates of v^{azov} and v_i^{azov} are changed due to the corrective term, complementing the in equation to equation for factor i (a result is v^{azov} (*) and v_i^{azov} (*)) (2), where m is the number of factors. Estimates $v_{i+1}^{azov(*)}$, etc. have already been previously adjusted for factors i+1, ..., and new ones are obtained by adding/subtracting Δv_i^{azov} to in equation i based on its sign.

$$\begin{cases} x^{azov} \succ x_1^{azov} + x_2^{azov} + x_3^{azov} + x_4^{azov} + x_5^{azov} \\ x^{azov} \prec x_1^{azov} + x_2^{azov} + x_3^{azov} + x_4^{azov} \\ x^{azov} \succ x_1^{azov} + x_2^{azov} + x_3^{azov} \\ x^{azov} \prec x_1^{azov} + x_2^{azov} \\ x_1^{azov} \succ x_2^{azov} + x_3^{azov} + x_4^{azov} + x_5^{azov} \\ x_1^{azov} \prec x_2^{azov} + x_3^{azov} + x_4^{azov} \\ x_1^{azov} \succ x_2^{azov} + x_3^{azov} \\ x_2^{azov} \prec x_3^{azov} + x_4^{azov} + x_5^{azov} \\ x_2^{azov} \succ x_3^{azov} + x_4^{azov} \\ x_3^{azov} \prec x_4^{azov} + x_5^{azov} \end{cases} \Rightarrow \begin{cases} v^{azov} > v_1^{azov} + v_2^{azov} + v_3^{azov} + v_4^{azov} + v_5^{azov} \\ v^{azov} < v_1^{azov} + v_2^{azov} + v_3^{azov} + v_4^{azov} \\ v^{azov} > v_1^{azov} + v_2^{azov} + v_3^{azov} \\ v^{azov} < v_1^{azov} + v_2^{azov} \\ v_1^{azov} > v_2^{azov} + v_3^{azov} + v_4^{azov} + v_5^{azov} \\ v_1^{azov} < v_2^{azov} + v_3^{azov} + v_4^{azov} \\ v_1^{azov} > v_2^{azov} + v_3^{azov} \\ v_2^{azov} < v_3^{azov} + v_4^{azov} + v_5^{azov} \\ v_2^{azov} > v_3^{azov} + v_4^{azov} \\ v_3^{azov} < v_4^{azov} + v_5^{azov} \end{cases} \quad (1)$$

$$\Delta v_i^{azov} = \frac{v_{i+1}^{azov(*)} + v_{i+2}^{azov(*)} + \ldots + v_m^{azov(*)}}{m-1}, \quad (2)$$

Similar to the previous step, adjustments according to formula (2) are done sequentially from bottom to top based on the inequations of the system (1). If there are several inequations to adjust one factor, the compliance control of the previously adjusted score is done - whether the inequation that is higher than the inequation for which this score was obtained is correct. If this is not the case, then they define the correction of the estimate from the inequation above and the half-sum of the two estimates.

This procedure is carried out for all five basic sets of superfactors and factors; as a result, the following scores for their sets are obtained (Table 3).

We carry out this procedure for all sets of superfactors and their factors/subfactors, then we find (xxxx marks the route) estimates: $v^{xxxx(*)}$ – route superfactors; $v_i^{xxxx(*)}$ – route factors; $v_{ij}^{xxxx(*)}$ – transportation subfactors. We convert the results into weights ($w^{xxxx(*)}$, $w_i^{xxxx(*)}$, $w_{ij}^{xxxx(*)}$), these are complex, basic, private risks:

$$w^{xxxx(*)} = \frac{v^{xxxx(*)}}{v^{azov(*)} + v^{balt(*)} + v^{iran(*)} + v^{east(*)} + v^{asia(*)}}. \quad (3)$$

For logistic factors, the sum of their weights is 1, and initially the calculations are similar (4).

Taking into account that these factors form their corresponding superfactors, we scale them relative to their superfactors as follows (i = 1,...,5) – see (5).

For subfactors, converting their estimates to weights is similar – see (6).

Moreover, as above, these values are calibrated by previously obtained values of logistic factors formed by a set of subfactors found above – see (7).

According to clause 2, we look for risks as the difference of value of strategy components weights from one – see (8).

$$w_i^{xxxx} = \frac{v_i^{xxxx(*)}}{v_1^{xxxx(*)} + v_2^{xxxx(*)} + v_3^{xxxx(*)} + v_4^{xxxx(*)} + v_5^{xxxx(*)}}, i = 1,...,5. \quad (4)$$

$$\left.\begin{array}{l} w_i^{azov(*)} = w_i^{azov} \cdot w^{azov(*)}; w_i^{balt(*)} = w_i^{balt} \cdot w^{balt(*)}; w_i^{iran(*)} = w_i^{iran} \cdot w^{iran(*)}; \\ w_i^{east(*)} = w_i^{east} \cdot w^{east(*)}; w_i^{asia(*)} = w_i^{asia} \cdot w^{asia(*)}. \end{array}\right\} \quad (5)$$

$$w_{ij}^{xxxx} = \frac{v_{ij}^{xxxx(*)}}{v_{i1}^{xxxx(*)} + v_{i2}^{xxxx(*)} + v_{i3}^{xxxx(*)}}, i = 1,...,5,\ j = 1,...,3. \quad (6)$$

$$\left.\begin{array}{l} w_{ij}^{azov(*)} = w_{ij}^{azov} \cdot w_i^{azov(*)}; w_{ij}^{balt(*)} = w_{ij}^{balt} \cdot w_i^{balt(*)}; w_{ij}^{iran(*)} = w_{ij}^{iran} \cdot w_i^{iran(*)}; \\ w_{ij}^{east(*)} = w_{ij}^{east} \cdot w_i^{east(*)}; w_{ij}^{asia(*)} = w_{ij}^{asia} \cdot w_i^{asia(*)}, (i = 1,...,5,\ j = 1,...,3). \end{array}\right\} \quad (7)$$

$$r^{xxxx} = 1 - w^{xxxx(*)}; r_i^{xxxx} = 1 - w_i^{xxxx(*)}, i = 1,...,5; r_{ij}^{xxxx} = 1 - w_{ij}^{xxxx(*)}; i = 1,...,5,\ j = 1,...,3. \quad (8)$$

Table 3: Scheme of organization of logistics factors for wheat transportation.

Route superfactors	*Logistics Factors*					*Trading ways*
Parameter / *Path*	*Grain source*	*Railway route*	*Point of shipment*	*Shipment center*	*Customer pool*	
$\boldsymbol{v^{azov(*)}}$	$v_1^{azov(*)}$	$v_2^{azov(*)}$	$v_3^{azov(*)}$	$v_4^{azov(*)}$	$v_5^{azov(*)}$	*– for Azov-Black Sea direction*
$\boldsymbol{v^{balt(*)}}$	$v_1^{balt(*)}$	$v_2^{balt(*)}$	$v_3^{balt(*)}$	$v_4^{balt(*)}$	$v_5^{balt(*)}$	*– for Baltic (EU) direction*
$\boldsymbol{v^{iran(*)}}$	$v_1^{iran(*)}$	$v_2^{iran(*)}$	$v_3^{iran(*)}$	$v_4^{iran(*)}$	$v_5^{iran(*)}$	*– for Caspian (Iran) direction*
$\boldsymbol{v^{east(*)}}$	$v_1^{east(*)}$	$v_2^{east(*)}$	$v_3^{east(*)}$	$v_4^{east(*)}$	$v_5^{east(*)}$	*– for Far Eastern (South-East Asia) direction*
$\boldsymbol{v^{asia(*)}}$	$v_1^{asia(*)}$	$v_2^{asia(*)}$	$v_3^{asia(*)}$	$v_4^{asia(*)}$	$v_5^{asia(*)}$	*– for Central Asia-India direction*

Based on pairwise comparison data (for example, for the Azov-Black Sea direction, see Table 2), using a modification of the sequential preference procedure, we obtain a system of preferences and corresponding scoring in equations:

$$\left\{\begin{array}{l} v_1^{azov} > \sum_{j=1}^{3} v_{1j}^{azov} \\ v_1^{azov} < \sum_{j=1}^{2} v_{1j}^{azov} \\ v_{11}^{azov} > \sum_{j=2}^{3} v_{1j}^{azov} \end{array}\right. \quad \left\{\begin{array}{l} v_2^{azov} > \sum_{j=1}^{3} v_{2j}^{azov} \\ v_2^{azov} < \sum_{j=1}^{2} v_{2j}^{azov} \\ v_{21}^{azov} > \sum_{j=2}^{3} v_{2j}^{azov} x \end{array}\right. \quad \left\{\begin{array}{l} v_3^{azov} > \sum_{j=1}^{3} v_{3j}^{azov} \\ v_3^{azov} < \sum_{j=1}^{2} v_{3j}^{azov} \\ v_{31}^{azov} > \sum_{j=2}^{3} v_{3j}^{azov} x \end{array}\right. \quad \left\{\begin{array}{l} v_4^{azov} > \sum_{j=1}^{3} v_{4j}^{azov} \\ v_4^{azov} < \sum_{j=1}^{2} v_{4j}^{azov} \\ v_{41}^{azov} > \sum_{j=2}^{3} v_{4j}^{azov} \end{array}\right. \quad \left\{\begin{array}{l} v_5^{azov} > \sum_{j=1}^{3} v_{5j}^{azov} \\ v_5^{azov} < \sum_{j=1}^{2} v_{5j}^{azov} \\ v_{51}^{azov} > \sum_{j=2}^{3} v_{5j}^{azov} \end{array}\right.$$

According to the previously described Churchman-Ackoff procedure, the initial values of the subfactor scores v_{ij}^{azov} are determined, and then they are adjusted, resulting in $v_{ij}^{azov(*)}$. At the same time, the scores of the factors v_i^{azov} involved in these calculations have already been previously determined from the system of priorities of superfactors and factors in the calculations above, and they are equal to $v_i^{azov(*)}$. Therefore, without changing during these calculations, they become a natural reference scale, where their score is the maximum value.

The specified procedure of sequential preferences applies not only to factors and subfactors with ‘azov’ determinants, but also to indicators with other determinants (balt, iran, east, asia). Thus, as a result of applying the sequential preference procedure, the following set of estimates for transportation

subfactors is obtained (Table 4). The risk map present in Fig. 1.

Table 4: Scheme of organization of sub-factors of wheat transportation.

	Grain source	Railway route	Point of shipment	Transportation center	Customer pool	
Price of 1 t. of grain:	$v_{11}^{azov(*)}$	$v_{21}^{azov(*)}$	$v_{31}^{azov(*)}$	$v_{41}^{azov(*)}$	$v_{51}^{azov(*)}$	– for Azov-Black Sea direction
Max grain export:	$v_{12}^{azov(*)}$	$v_{22}^{azov(*)}$	$v_{32}^{azov(*)}$	$v_{42}^{azov(*)}$	$v_{52}^{azov(*)}$	
Grain cultivar:	$v_{13}^{azov(*)}$	$v_{23}^{azov(*)}$	$v_{33}^{azov(*)}$	$v_{43}^{azov(*)}$	$v_{53}^{azov(*)}$	
Tariff of storage:	$v_{11}^{balt(*)}$	$v_{21}^{balt(*)}$	$v_{31}^{balt(*)}$	$v_{41}^{balt(*)}$	$v_{51}^{balt(*)}$	– for Baltic (EU) direction-
Max throughput capacity:	$v_{12}^{balt(*)}$	$v_{22}^{balt(*)}$	$v_{32}^{balt(*)}$	$v_{42}^{balt(*)}$	$v_{52}^{balt(*)}$	
Movement velocity:	$v_{13}^{balt(*)}$	$v_{23}^{balt(*)}$	$v_{33}^{balt(*)}$	$v_{43}^{balt(*)}$	$v_{53}^{balt(*)}$	
Tariff of storage:	$v_{11}^{iran(*)}$	$v_{21}^{iran(*)}$	$v_{31}^{iran(*)}$	$v_{41}^{iran(*)}$	$v_{51}^{iran(*)}$	– for Caspian (Iran) direction
Max. volume of storage:	$v_{12}^{iran(*)}$	$v_{22}^{iran(*)}$	$v_{32}^{iran(*)}$	$v_{42}^{iran(*)}$	$v_{52}^{iran(*)}$	
Max. time of storage:	$v_{13}^{iran(*)}$	$v_{23}^{iran(*)}$	$v_{33}^{iran(*)}$	$v_{43}^{iran(*)}$	$v_{53}^{iran(*)}$	
Tariff of sea transportation:	$v_{11}^{east(*)}$	$v_{21}^{east(*)}$	$v_{31}^{east(*)}$	$v_{41}^{east(*)}$	$v_{51}^{east(*)}$	– for Far Eastern (South-East Asia) direction
Loss coefficient:	$v_{12}^{east(*)}$	$v_{22}^{east(*)}$	$v_{32}^{east(*)}$	$v_{42}^{east(*)}$	$v_{52}^{east(*)}$	
длина перевозки:	$v_{13}^{east(*)}$	$v_{23}^{east(*)}$	$v_{33}^{east(*)}$	$v_{43}^{east(*)}$	$v_{53}^{east(*)}$	
Grain sale price:	$v_{11}^{asia(*)}$	$v_{21}^{asia(*)}$	$v_{31}^{asia(*)}$	$v_{41}^{asia(*)}$	$v_{51}^{asia(*)}$	*– for Central Asia-India direction*
Grain unloading time	$v_{12}^{asia(*)}$	$v_{22}^{asia(*)}$	$v_{32}^{asia(*)}$	$v_{42}^{asia(*)}$	$v_{52}^{asia(*)}$	
Ship maintenance charges:	$v_{13}^{asia(*)}$	$v_{23}^{asia(*)}$	$v_{33}^{asia(*)}$	$v_{43}^{asia(*)}$	$v_{53}^{asia(*)}$	

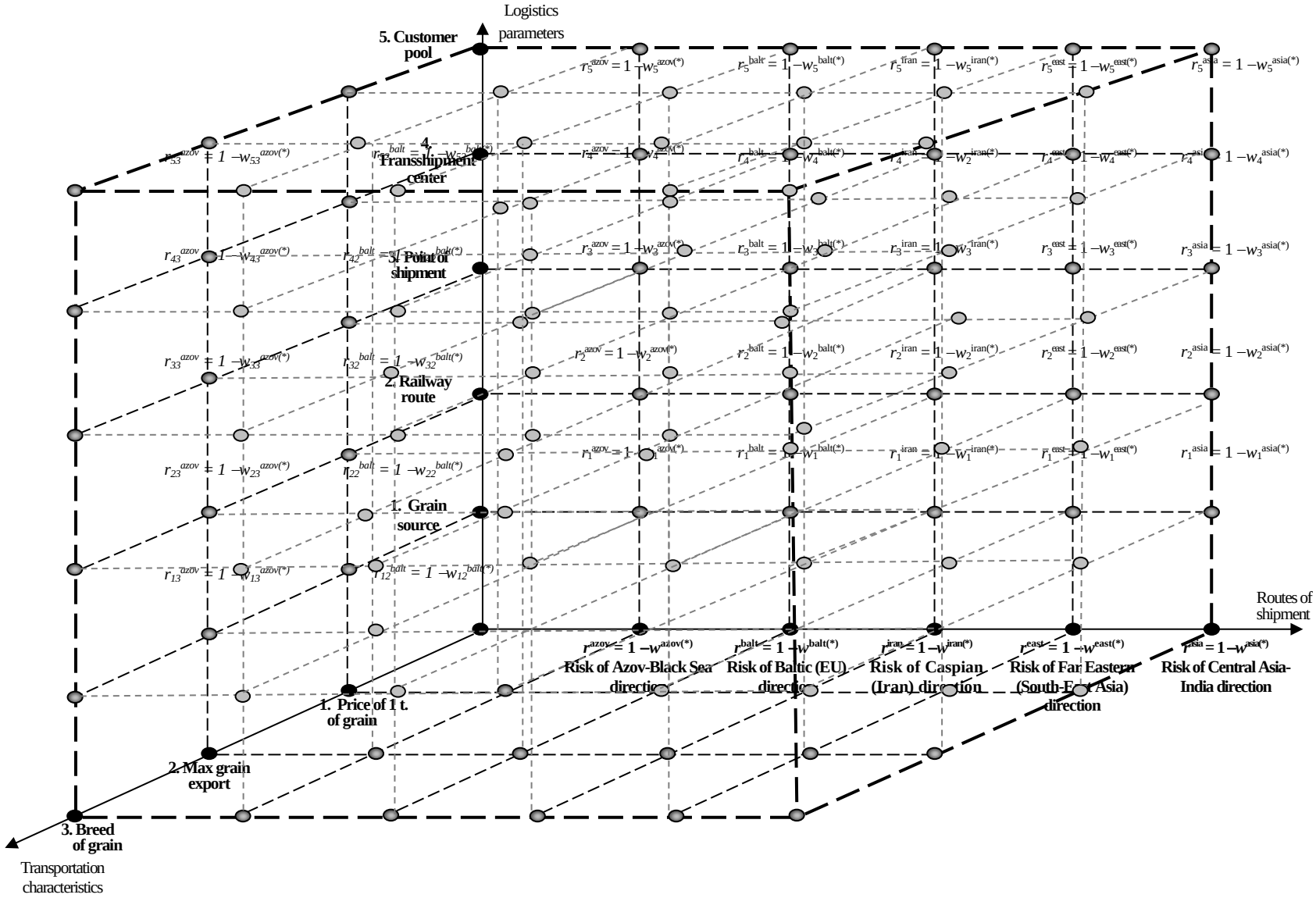

Figure 1: Sketch fragment of a three-dimensional risk map of wheat transportation strategies.

Let us show a three-dimensional risk map, where complex risks run along the “routes of shipment” axis, basic risks are set along the nodes of the lattice formed by the “routes of shipment” / “logistics parameters” axes, and particular risks are correlated with the nodes of the cube constructed by moving this lattice along the “transportation characteristics". Only part of these parameters are shown in Fig. 1 due to their large number.

Note that a three-dimensional map is noticeably different from a two-dimensional map in terms of the clarity of the analysis results in the context of the multi-parameter nature of the research problem. This is clearly seen from the results of a similar study (Dalisova, Yamshchikov, 2021) where the authors interpret the results based on two-dimensional risk maps.

4 CONCLUSIONS

The socio-economic impact on most areas of life is determined by the role of information uncertainty. The need to take into account all risk factors in conditions of unknown external influences is obvious. It is impossible to develop an appropriate model tool with limited resources, and a decision made was to turn to experts. Their experience in assessing similar situations determines the weights of problem-solving strategies, taking into account two aspects of risk management.

1. Experts very roughly evaluate strategies, assigning their ranks. In addition, some of the risks are complex, i.e. are composed of risks of a lower level, which creates a hierarchy of risks that is not fully understood by the expert.

2. The expert scales risks inaccurately - their appearance depends on a large set of factors. However, the gradation of possible strategies is simpler for him/her, depending, according to the expert, on the availability of resources and external influences.

Taking these aspects into account served a source of scientific novelty in the article.

I. A modification of the Churchman-Ackoff sequential preference procedure, which is not applied to factors equal in weight, but to those where one of them is a composite of other factors. These other factors are later compared with those that form them, repeating the Churchman-Ackoff procedure. As a result, we have a hierarchy of all factors.

II. Working with the “weight - risk” dichotomy, where risk adds weight up to one as the sum of the probabilities of incompatible events, means adopting a strategy or abandoning it due to the appearance of a risk that makes it impossible. It also became obvious that it is more convenient to use the constructed three-dimensional risk map and build it using 3-D modeling tools based on repositories created with the use of OLAP technology.

Similarly, based on the results of constructing a risk map traditionally used in risk management, it became obvious that using such a map, as well as building it, is more convenient when using special graphical modeling tools. It is advisable to accumulate information for such a presentation in data warehouses built using OLAP technology. The effect of such an analytical tool can be very significant, which has been repeatedly proven by research (see, for example, (Eremenko, Shumilin, Shamkina, Shumilina, Makartsova, Kravchenko, Evsyukova, Filippova, Yatsuk, 2020) and (Khulkhachieva, Badmahalgaev, Berikova, 2022)).

Further research into the issues discussed in this article may be devoted to the development of a risk management support system when planning the transportation of grain products for export. The authors have experience in building such systems, the most striking of which is the study and minimization of the risk background of an educational organization (Shevtsova, Kanev, Poletaikin, Kuleshova, 2019). In addition to the methodology for risk management of educational activities, the article (Shevtsova, Kanev, Poletaikin, Kuleshova, 2019) describes the technology for organizing the risk management process. With minor modifications, this technology can be applied to the problem of organizing risk-sustainable transportation of grain export.

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