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Direct Fuzzy Evaluation of Financial Risk "Chains" of an Organisation

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ABSTRACT

The **object of the research** is the diagnosis and evaluation of financial risks in order to create an effective risk management policy. The **subject of the research** is the methodology of direct fuzzy evaluation of financial risk "chains" of an organisation. The **relevance** of the problem is due, on the one hand, to the dynamic and chaotic macro-environment and the business environment of organisations, on the other hand, to the drawback of the analytical and expert methods used to assess financial risks. The former, moreover, imply statistical data processing and operate with quantitative measures. For the latter, the difficulty is the impossibility of their application in a short time interval. From the perspective of operational risk management, financial risks deserve special attention since the effective operation of the entire organisation depends on them. The **purpose of the research** is to form a methodology for direct fuzzy evaluation of financial risk "chains" of an organisation. The authors apply **the methods** of mathematical forecasting, fuzzy modelling, calculation of financial and economic indicators, and expert risk assessment. The proposed methodology consists of 12 stages, beginning with the analysis of business processes and the identification of financial risks of the organisation. The main stage is the construction of a fuzzy evaluation model and the calculation of indicators: the probability of occurrence and realization of risks and risky situations of the financial risk "chains", and the degree of confidence of the calculations conducted. The final stage of the methodology is an analysis of the results obtained to adjust the selected development strategy of the organisation, and the choice of methods for managing identified financial risks bearing the most significant financial and economic losses. The authors **conclude** the developed methodology allows to accurately assess the threat of a certain risk "chain" and losses from the implementation of specific risk situations for any organisation in the conditions of dynamic changes in internal and external elements of the business environment. The advantage of the methodology should be considered in the comparability of the accuracy of the evaluation and the low cost of modelling.
Keywords: financial risks; risk management; risk "chain"; fuzzy evaluation model; fuzzy direct evaluation; dynamic environment; financial and economic losses; organisation's business-processes

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INTRODUCTION

In the context of growing instability, uncertainty, complexity and ambiguity of the current economic and political situation, which is reflected in the VUCA world concept, which describes the business environment as chaotic and rapidly changing, the importance of risk management of business entities is increasing. In this respect, effective risk management should be based on a dynamic approach that involves many factors, including the time factor, in the process of improving the efficiency of management decisions based on forecasts. It is often extremely difficult even for highly experienced managers to give a quantitative assessment of risks for the purposes of subsequent economic and mathematical modeling. Such conditions hinder the adoption of high-quality decisions, which, in turn, must be supported by dynamic models and methods that take into account uncertainty.

Organizations most often use expert-analytical methods to analyze and assess risky situations. At the same time, analytical methods require a large amount of statistical data and are generally focused on quantitative indicators, while expert methods can be difficult in the rapid assessment of uncertainties and risks due to the lack of highly qualified analysts and significant time costs [1].

An economic entity cannot optimize the entire existing set of risks due to the objective nature of their occurrence, therefore, as part of operational risk management, it is necessary to evaluate only those that can be formally described and minimized by the organization. From this point of view, financial risks associated with the purchasing power of money, including inflation risks expectations, investment risks, risks related to the organizational structure of management, and the business model being implemented, deserve special attention.

Since the emergence and growth of risks are preceded by one or another reason, forecasting and preventive assessment of the likelihood of occurrence and development of a risk situation is relevant. This can be fully implemented on the basis of a systematic and integrated approach to analysis, which allows not only to identify the risk but also to determine the causes of its occurrence in the external and internal environment of the organization, and its relationship with other risks and the likelihood and severity of possible consequences.

Methods and models based on fuzzy logic and integrated into the organization's information system allow for high-precision risk assessment and low labor and time costs, taking into account the consistency and complexity of the analysis [2]. Such models make it possible to consider all the necessary elements of the organization's risk system, both quantitative and qualitative descriptions of them, in the mathematical formulations of fuzzy logic, sets, and linguistic variables, taking into account the uncertainty and relationships of their occurrence. Methods based on the use of fuzzy models are a management decision support tool that allows developing a strategy based on the diagnosis and optimization of risks, comprehensively exploring the financial and economic aspects of the functioning of the organization, and significantly reducing the labor, financial and time costs of the organization on risk assessment and insurance costs.

RISK "CHAINS" OF ORGANIZATIONS

Currently, most organizations have formed a financial and economic mechanism for strategic management, which allows the development and selection of an organization's strategy, taking into account the assessment of possible risks, as well as on the basis of modern analytical methods and technologies. An essential element of this mechanism is the risk management process, during which the mathematical apparatus of economic statistics (for example, mathematical expectation, variance, standard deviation, semi-dispersion) and expert methods (for example, the Delphi method, scenario method) are used [3]. These methods mainly assess a specific risk due to the current

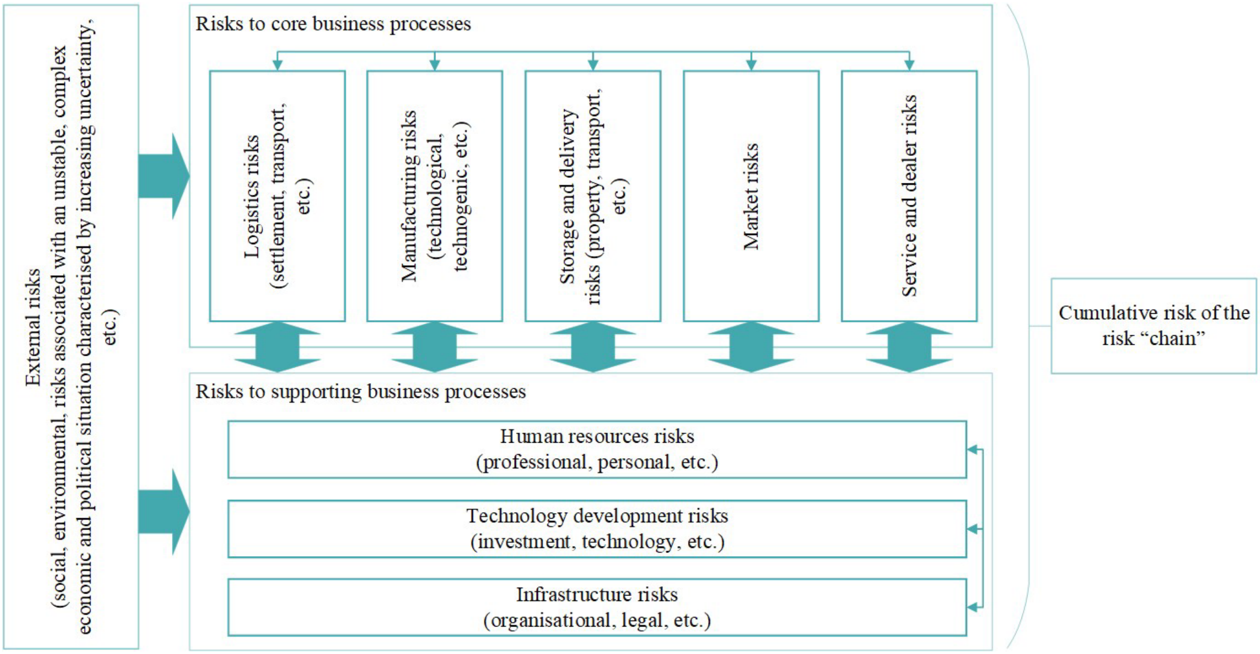

Fig. 1. **The risk "chain" of a manufacturing organisation**

Source: compiled by the authors.

situation but do not take into account its development trends, links with other risks, events, and factors that contribute to their occurrence.

A partial and unstructured analysis of these relationships is carried out in accordance with the standard risk management technology adopted in the organization after risk assessment during the decision-making procedure in risk situations, for example, when building an event tree or a decision tree [4]. Such a traditional approach in the face of increasing uncertainty, instability, and ambiguity of the current economic and political situation is gradually losing its effectiveness, since it often does not meet the objectives of increasing management flexibility, including in the field of operational and strategic risk management.

The noted shortcomings of the currently used risk assessment methods can be eliminated on the basis of an analysis of the main and auxiliary business processes. At the first stage, it is necessary to diagnose existing business processes, and in particular their state in terms of financial risks; identify critical areas of business processes in which there is a possibility of financial risk that can significantly affect the activities of the organization.

At the next stage, the relationships between risks are determined, on the basis of which it becomes possible to build their system, which we called the risk "chain". The structure of the risk "chain" (*Fig. 1*) is defined as an interconnected system of various risks arising from the environment of the organization. It should be noted that the risk "chain" includes both internal and external risks that characterize the current uncertain, unstable, difficult economic and political situation.

The "chain" in *Fig. 1* is generalized, therefore, for a specific production organization, it can only be used as a basis, followed by the specification of the types of risks, taking into account the specifics of business processes. Financial risks can arise in almost all links of the "chain" shown in *Fig. 1*, however, often affect other types of risks, due, for example, to the development of technologies, the state of infrastructure, the specifics of production, and marketing of finished products. Their identification and the establishment of relationships between them are important for the organization since the implementation of risky situations can be

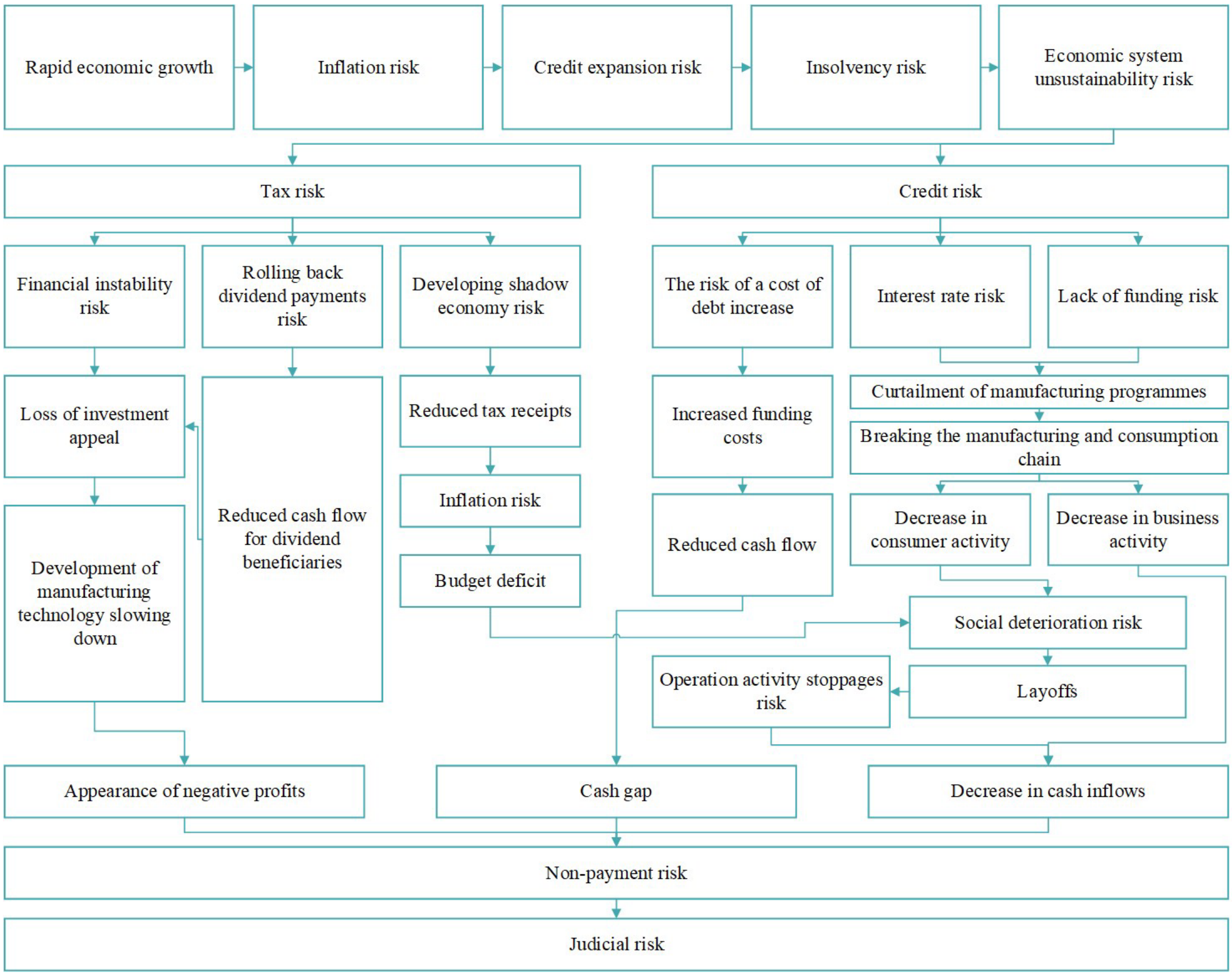

Fig. 2. **The financial risk "chain" of a manufacturing organisation**

Source: compiled by the authors.

accompanied by a cumulative effect, leading to serious losses. For example, underestimating the likelihood of the emergence of fundamentally new technologies that promote "disruptive" innovations can lead to an increased risk of not being in demand for finished products, liquidity risk, and also contribute to a drop in profits. At the same time, early identification of financial risks allows them to be described, evaluated, and optimized. The "chain" in *Fig. 2* illustrates one of the possible options for the relationship of various financial risks of a production organization.

When assessing various risks, analysts use traditional analysis methods, taking into account the characteristics of their types, which in some cases, in the absence of studies of risk factors, the magnitude of damage or the instability of the business environment, is inappropriate, unlike the use of expert methods or fuzzy modeling [1]. The latter are of particular relevance in modern conditions since they imply incomplete knowledge of all parameters, circumstances, and situations, and also take into account the multi-level structure of assessment, the different significance of indicators, as well as the presence of fuzzy compatibility relationship between them [4].

FUZZY EVALUATION MODEL FOR THE ANALYSIS OF THE FINANCIAL RISK "CHAIN"

The use of fuzzy logic in evaluating financial risk "chains" has a number of features. First of all, it is necessary to take into account the interpretation of this "chain" as a mathematical set containing the results of assessing the values of risk indicators and risk situations. These "chains" have a multilevel structure, due to the different significance for the organization of the dimensions included in it and the form of fuzzy connections between them, especially at the top of the hierarchical chain. Accordingly, at each level of the hierarchy, the indicators form subsets, each of which corresponds to the indicator of the neighboring higher level of the hierarchy. At each level of the hierarchy, starting from the second, there may be indicators that do not form subsets at a lower level. At the first level of the hierarchy, there is a subset of one (generalized) indicator. Each indicator is assigned a weight. Indicators belonging to one subset form a fuzzy compatibility relation [2]. These features justify the need to apply the methodology of direct fuzzy estimation, as well as the use of fuzzy production models.

Note that the construction of a "chain" of financial risks and risk situations allows us to determine the full space of prerequisites that are sources of risks or risk situations presented in the "chain", as well as the space of conclusions resulting from specific risks.

Representation of the relationship between various financial risks and risk situations in the form of a "chain" allows going to its composition by grouping it into subsets that have the following form:

$$R^{(i)}=\left\{R_1^{(i)},R_2^{(i)},\ldots,R_n^{(i)}\right\}, \qquad (1)$$

where $i=1,2,\ldots,I$; $n=1,2,\ldots,N$; $R_n^{(i)}$ is a subset of risks and risk situations at the i-th level of decomposition of the financial risk "chain" (zero level of decomposition, or $R^{(0)}$, is a "chain" of financial risks with aggregated assessment indicators); I — the number of levels of decomposition of the fuzzy evaluation model; N — the number of risks and risk situations or subsets at the i-th level of model decomposition.

After grouping by subsets, it is necessary for each value of the risk indicator at the i-th level of decomposition of the fuzzy evaluation model ($r_{n,j}^{(i)}$) to determine the correspondence with the subset of risks and risk situations at the (i + 1)-th evel of decomposition of the financial risk "chain":

$$r_{n,j}^{(i)}\leftrightarrow R_m^{(i+1)}=\left\{r_{m,1}^{(i+1)},\ldots,r_{m,p}^{(i+1)},\ldots,r_{m,p_s}^{(i+1)}\right\}, \qquad (2)$$

where I is the number of decomposition levels of the fuzzy evaluation model ($i=1,2,\ldots,I-1$); N — the number of risks and risk situations or subsets at the i- th level of model decomposition ($n=1,2,\ldots,N$); M — the number of risks and risk situations or subsets at the (i + 1)-th level of model decomposition ($m=1,2,\ldots,M$); p_s — the number of values of risk indicators from the subset $R_m^{(i+1)}$ of the (i + 1)-th level of model decomposition, correlated with the j-th indicator $r_{n,j}^{(i)}$ from the subset $R_m^{(i)}$ of the i-th level of model decomposition ($p=1,2,\ldots,p_s$).

It should be noted that in order to build a fuzzy evaluation model, it is necessary to determine the significance or weights of all risks and risk situations in the constructed financial risk "chain" at each level of model decomposition:

$$r_{n,j}^{(i)}\leftrightarrow w_{n,j}^{(i)}, \qquad (3)$$

where $n=1,2,\ldots,N$; $i=1,2,\ldots,I$; $j=1,2,\ldots,p_s$; $w_{n,j}^{(i)}$ — the significance (weight) of the risk or risk situation $r_{n,j}^{(i)}$.

The main element of the fuzzy evaluation model is the fuzzy compatibility relationship between risks and risk situations (values of risk indicators), given in the following form:

$$\tilde{K}_n^{(i)}=\left\{\left(\left(r_{n,q}^{(i)},r_{n,l}^{(i)}\right)/c_{n,ql}^{(i)}\right)\right\}, \qquad (4)$$

where $n=1,2,\ldots,N$; $i=1,2,\ldots,I$; $q,l\in\{1,2,\ldots,p_s\}$; $\tilde{K}_n^{(i)}$ — a fuzzy compatibility relation between risks and risk situations (values of risk indicators) of the subset $R_n^{(i)}$; $c_{n,ql}^{(i)}$ is the degree of compatibility of risks and risk situations (values of risk indicators) $r_{n,q}^{(i)}$ и $r_{n,l}^{(i)}$.

For the organization's financial risk "chain" compatibility is interpreted as the impact of one risk (risk situation) on another through the transfer of the "added effect of the total risk" (increase in danger or threat to the organization, as well as an increase in the

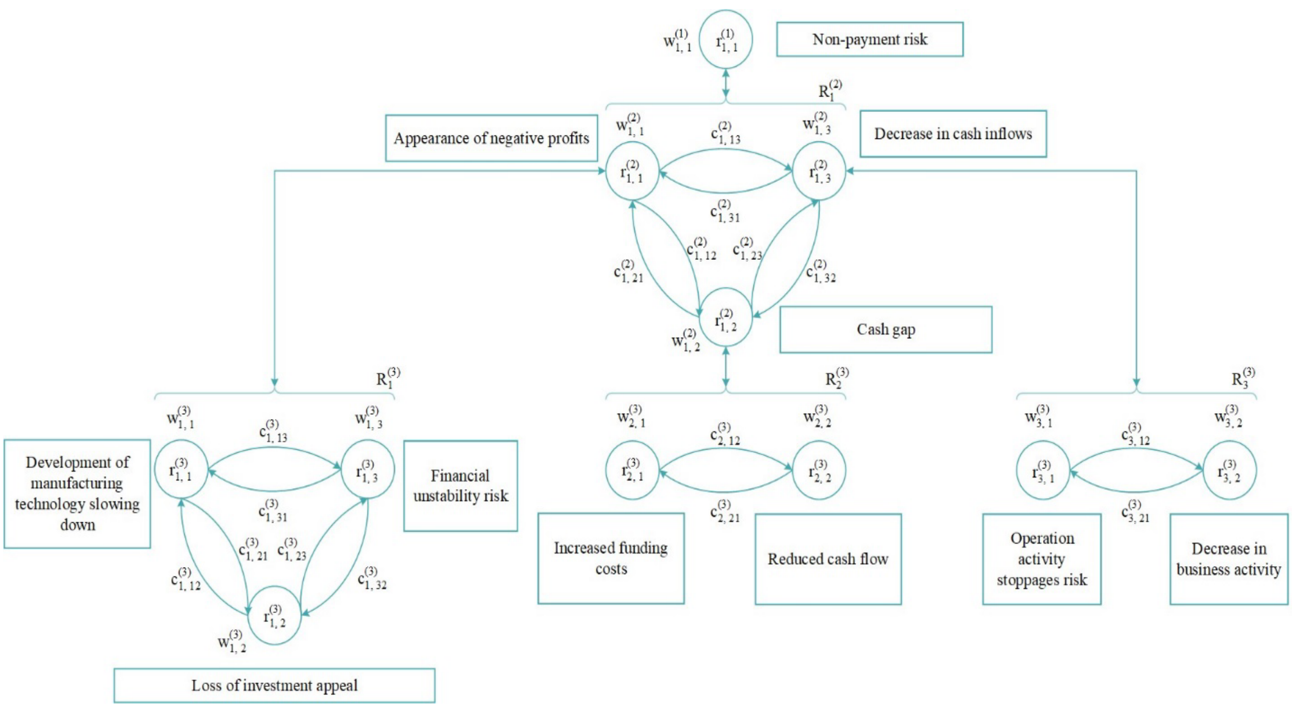

Fig. 3. **Fuzzy evaluation model of the financial risk "chain" of a manufacturing organisation (fragment)**
Source: compiled by the authors.

severity of consequences for the organization in case of passing the elements of the "chain"), a fuzzy compatibility factor is introduced to prevent double counting of risk.

Based on formulas (1)–(4), the proposed fuzzy evaluation model in a formalized form can be represented as formula (5).

$$\begin{cases} R^{(i)} = \left\{R_1^{(i)}, R_2^{(i)}, \ldots, R_n^{(i)}\right\}, \\ R_n^{(i)} = \left\{r_{n,1}^{(i)}, \ldots, r_{n,p}^{(i)}, \ldots, r_{n,p_s}^{(i)}\right\}, \\ r_{n,j}^{(i)} \leftrightarrow R_m^{(i+1)} = \left\{r_{m,1}^{(i+1)}, \ldots, r_{m,p}^{(i+1)}, \ldots, r_{m,p_s}^{(i+1)}\right\}, i = 1, 2, \ldots, I-1, \\ r_{n,p}^{(i)} \leftrightarrow w_{n,j}^{(i)}, \\ \tilde{K}_n^{(i)} = \left\{\left(\left(r_{n,q}^{(i)}, r_{n,l}^{(i)}\right) / c_{n,ql}^{(i)}\right)\right\}, \end{cases} \quad (5)$$

where $i = 1, 2, \ldots, I$; $n = 1, 2, \ldots, N$; $p = 1, 2, \ldots, p_s$; $m = 1, 2, \ldots, M$; $j = 1, 2, \ldots, p_s$; $q, l \in \{1, \ldots, p_s\}$.

Fig. 3 shows a fragment of the "chain" of financial risks and risk situations of a production organization, shown in *Fig. 2*. It should be noted that the relationship between the risk (risk situation) at the *i*-th level of decomposition of the fuzzy evaluation model and the set of risks (risk situations) at the (*i* – 1)-th decomposition level has the form of a transition between decomposition levels with the accumulation of an additional effect of cumulative risk, increasing the threat of the risk "chain" for the organization, as well as the increase in the severity of the consequences for the organization.

The connection of the higher levels of decomposition of the fuzzy assessment model of the financial risk "chain" of the organization is established, in particular, the connection of decomposition levels with the elements: $R_1^{(2)}$ and $r_{1,1}^{(1)}$ (or $R_1^{(1)}$), s specified using the MISO structure (many inputs — one output) and is a cascade connection of several (for marked levels of decomposition of the fuzzy estimation model — three) bases of fuzzy production rules that implement the mapping of input variables to the output variable [4–6]. *Fig. 4* shows a cascade fuzzy model for assessing the impact of a combination of risks and risk situations, which is a space of risk prerequisites (risk situations), which is at a higher level of decomposition, on this risk (risk situation) for a financial risk "chain" and risk situations organization is shown in *Fig. 2*.

The fuzzy evaluation model of the "chain" of financial risks and risk situations of the

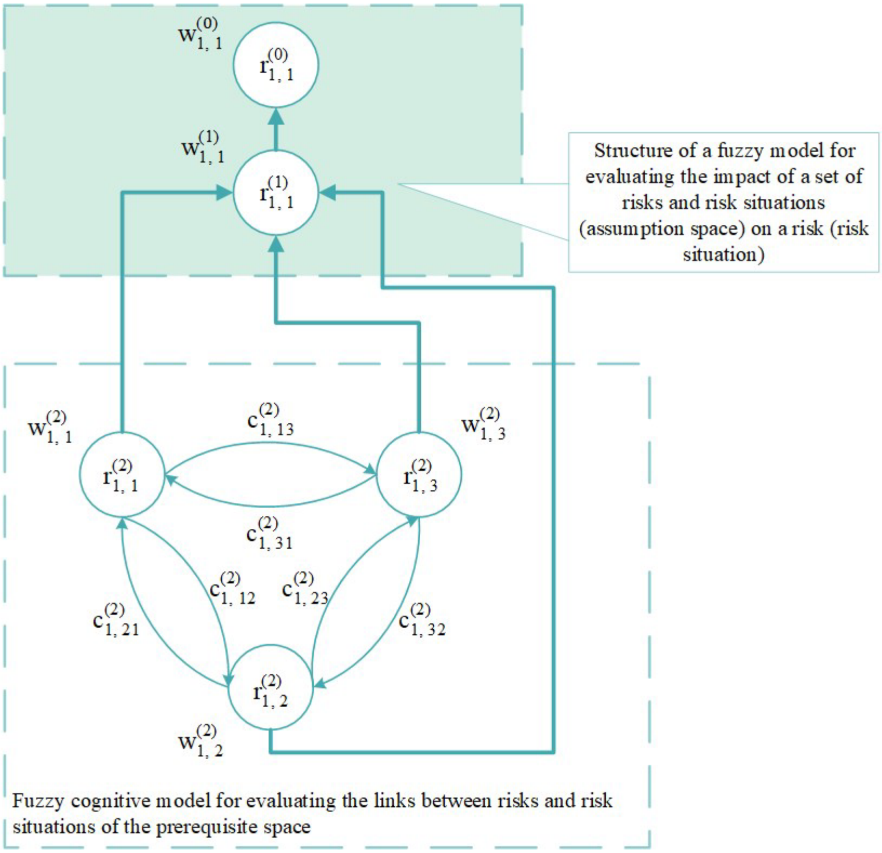

Fig. 4. **Example of a framework for evaluating the impact of risks and risk situations at the *i* decomposition level of a fuzzy evaluation model on a risk or risk situation at the (*i* + 1) decomposition level**

Source: compiled by the authors.

organization, described above, defines the direct fuzzy assessment algorithm. It should be noted that the evaluation process starts from the lower levels of decomposition of the fuzzy evaluation model, is carried out in "direct" order, i.e. from the lower levels of decomposition to the upper levels of decomposition, and ends with finding the totality of indicators for evaluating the "chain" of financial risks at the zero level of decomposition.

METHODOLOGY FOR DIRECT FUZZY EVALUATION OF THE "CHAIN" OF FINANCIAL RISKS OF AN ORGANIZATION

The proposed methodology for direct fuzzy evaluation of the "chain" of financial risks of an organization consists of the following main stages.

Stage 1. Analysis of the existing business processes of the organization, study of the current financial situation, and identification of financial risks.

To build an effective fuzzy evaluation model, it is necessary to involve experts (for example, leading specialists from consulting organizations) in the analysis of the current activities of the organization, in this case, it is necessary to present the information received in the form of *Table 1*, for the subsequent calculation of the confidence degree (reliability) of the assessment, as well as the interpretation of the relationship between risk, the prerequisite space and the conclusion space in the form of a "chain" of financial risks and the organization's risk situation.

Stage 2. Building the organization's financial risks "chain" clarifies the links between risks and risk situations.

Based on the information available and systematized in the form of *Table 1* on the identified financial risks, a risk "chain" of a production organization is formed, on

Table 1

Identified financial risks

Notation	Risk	Description of the prerequisite space	Description of the conclusion space	Risk value	Confidence degree
r_1					
r_2					
...					
r_n					

Source: compiled by the authors.

which the links are marked, in which the occurrence of financial risks is likely. On the basis of the marked links, the organization's financial risk "chain" is compiled. It should be noted that risk situations can be additionally included in this chain if they are significant in the prerequisite space or the conclusion space and are accompanied by a cumulative effect leading to serious losses with the impossibility of converting it into an emerging financial risk [7].

Stage 3. Building a fuzzy evaluation model of the financial risk "chain".

The financial risk "chain" obtained at the previous stage allows us to proceed to fuzzy modeling. At this stage, it is important to establish the relationship between the identified financial risks (risk situations), describe their nature, and identify the final risk (risk situation) that has the greatest additional effect on the total risk. After identifying this element of the financial risk "chain", it is necessary to decompose it based on the established links, thereby obtaining a hierarchical structure of assessment indicators, each of which correlates with the significance (weight) of the corresponding risk or risk situation [8]. After excluding minor financial risks by aggregating them with an adjacent risk or risk situation, a fuzzy model for evaluating the financial risk "chain" is built, which is shown in *Fig. 3*.

Stage 4. Identifying the degree of compatibility of aggregate indicators of financial risks and risk situations.

At this stage, according to formula (4), fuzzy compatibility relationships between risks and risk situations are specified. The emerging fuzzy relationships in the "chain" of the organization's financial risks are the determinants of subsequent fuzzy convolution operations. However, a direct method for determining the degree of compatibility described by formula (4) cannot always be used, since at present the business environment of an organization is often described as chaotic and rapidly changing, and how likely is the risk of a situation or risks that have not previously been described and are not amenable to "clear" evaluation [9]. In these cases, it is possible to use an indirect method based on comparing the levels of compatibility of risks and risk situations with the levels of the Harrington scale (LL — "Low level" LML — "Lower middle level", ML — "Middle level", HML — "Higher middle level", HL — "High level") [2]. Accordingly, formula (4) is supplemented by formula (6).

$$c_{n,ql}^{(i)} = c_z \in C = \{LL, LML, ML, HML, HL\}, z = 1, 2, \ldots 5, \quad (6)$$

where $c_{n,ql}^{(i)}$ is the degree of compatibility of risks and risk situations (values of risk indicator) $r_{n,q}^{(i)}$ and $r_{n,l}^{(i)}$

($n=1,2,\ldots,N; i=1,2,\ldots,I; q,l\in\{1,2,\ldots,p_s\}$); z — is the index of the corresponding element of the set C, containing the levels of the Harrington scale.

At the same time, for risks (risk situations) that are at the same level of decomposition of the fuzzy evaluation model, but do not have logically established relationships, the degree of compatibility of these risks and risk situations (values of risk indicators) is considered to be the LL level according to the above Harrington scale for subsequent aggregation of the set of risks and establishing the cumulative added effect of the cumulative risk in the transition between levels of decomposition of the model.

Stage 5. Setting a strategy for assessing a subset of risk indicators or risk situations of the decomposition level of a fuzzy model for assessing a "chain" of financial risks.

The transition between the levels of decomposition of the fuzzy model for assessing the financial risk "chain" is accompanied by the cumulative effect of accumulating the additional effect of the total risk, which leads to serious losses for the organization. Therefore, the technique uses a parameterized family of convolution operations [10] described by formula (7).

$$med(r_k, r_l; \alpha), k,l \in \{1,2,\ldots,n\}, \quad (7)$$

where $med(r_k, r_l; \alpha)$ is a parameterized operation of fuzzy convolution of the values of risk indicators and risk situations at the same level of decomposition of the fuzzy assessment model of the financial risk "chain" of a production organization; k,l — indices of risks or risk situations at the i-th level of decomposition; α — the fuzzy convolution parameter ($\alpha \in [0,1]$).

The value of the parameter α must correspond to the criterial levels of compatibility of aggregate risk indicators or risk situations at the (i + 1)-th level of decomposition of the fuzzy assessment model on the Harrington scale [11]. Since the proposed methodology provides for both the calculation of the aggregate indicator of the added effect of the total risk for the entire "chain" of financial risks, and the calculation of the aggregate indicator of the degree of confidence, when moving between decomposition levels, various strategies for evaluating subsets of risk indicators or risk situations are provided.

Strategy 1 — the fuzzy assessment from the least compatible risks (risk situations) to the most compatible ones with the summation of the accumulated added effect of the total risk during the transition between decomposition levels of the fuzzy assessment model of the financial risk chain. The choice of this strategy is determined by the simultaneous use of direct and indirect methods for determining the degrees of compatibility of risks and risk situations, setting the order for viewing these degrees of compatibility, the consistent nature of the fuzzy convolution at each level of decomposition of the evaluation model [12–14].

Strategy 2 — the fuzzy assessment from the most compatible risks (risk situations) to the least compatible when moving between decomposition levels of the fuzzy evaluation model of the financial risk "chain". The choice of this strategy is determined by the presence of indicators of the degree of confidence [15] for each financial risk identified at stage 1, the absence of the need to use summation to reflect the cumulative effect, since the value of the aggregate indicator of the confidence degree does not show the predicted severity of the consequences of the full "chain" of financial risks, but the confidence degree in the result. The confidence degree in the proposed methodology is measured on a scale from 0.00 to 1.00 with a step of 0.01. If necessary, it is possible to increase the accuracy of the values of the confidence degree indicator for a more correct measurement of the accuracy of the result obtained. The calculation of the aggregated degree of confidence is carried out according to the same methodology, taking into account the noted feature.

Stages 6–7. Splitting the fuzzy compatibility relationship between risks and risk situations for the level of decomposition of the fuzzy evaluation model into compatibility classes. Selection and mapping of convolution operations to compatibility classes.

At this stage, in accordance with a certain strategy, the values of risk indicators and risk situations are aggregated, having the same degree of compatibility or close ones, belonging to the same level according to the Harrington scale used. At the same time, the order of the fuzzy convolution of these indicators within the corresponding subset of risks and risk situations is not important [16].

Stage 8. Modification of the fuzzy compatibility relationship between risks and risk situations for the decomposition level of the fuzzy evaluation model.

After a fuzzy convolution of risk indicators or risk situations, it is necessary to modify the fuzzy compatibility relationship between risks and risk situations and change the compatibility degree of other risks or risk situations that are in the same subset of risks, taking into account the new aggregate indicator of risks that are in the same compatibility class.

The implementation of steps 5–8 is cyclical or repetitive until the aggregation of all risk indicators and risk situations that are at the lower levels of the decomposition of the fuzzy assessment model of the organization's financial risk "chain" is achieved. After completion of all iterations, the analysis of the obtained structure of the fuzzy evaluation model for aggregated indicators takes place. In the methodology, two options for stage 9 are proposed.

Stage 9.1. It is used for a MISO structure, which is a cascading connection of a large number of input indicators of risks and risk situations and one resulting indicator. For this, in accordance with formula (5), the bases of fuzzy production rules are formed, as well as the structure of the fuzzy neural production network (ANFIS) [17, 18], which is shown in *Fig. 4*, in accordance with the number of input indicators of risks and risk situations.

Stage 9.2. It is used for other cases in which the fuzzy evaluation model from aggregated risk indicators (risk situations) does not have the form of a MISO structure. Within the framework of this stage, the structure of further fuzzy convolution of indicators is formed [19] [for example, in the form of formula (8)]:

$$R^{(0)} = h_u\left(h_y\left(\ldots\left(h_t\left(R_1^{(t)}, R_2^{(t)}\right), \ldots\right), R_n^{(y)}\right), R_n^{(u)}\right), \quad (8)$$

where *h(a, b)* — fuzzy convolution operation; *u, y, t* are indices of these operations corresponding to different levels of decomposition of the consistency of indicators, subsets of risks and risk situations.

Stage 10. Setting the weighted values of indicators of risk subsets and risk situations.

As noted earlier, effective risk management in a chaotic and rapidly changing business environment should be based on a dynamic approach, the conditions of uncertainty in which are characterized not only by the fact that the probability distribution law for uncertain factors is unknown, but also by the fact that the time factor becomes the most meaningful. In this regard, the proposed method of the direct fuzzy evaluation of the financial risk "chain" of an organization provides for the assessment of alternatives. To calculate alternatives, each risk indicator or risk situation is assigned a weighted fuzzy value of the evaluated alternative to find the best solutions [20–22] that provide an acceptable value of the aggregated value of indicators for the considered financial risk "chain".

Stage 11. Obtaining aggregated values of indicators for the complete financial risks "chain" and checking the applicability of the obtained values based on the value of the aggregated indicator "confidence degree".

Stage 12. Correction of the selected strategies for the development of the organization, the choice of risk management methods.

Thus, the proposed method of direct fuzzy evaluation of the financial risk "chain" of an organization, based on the analysis of

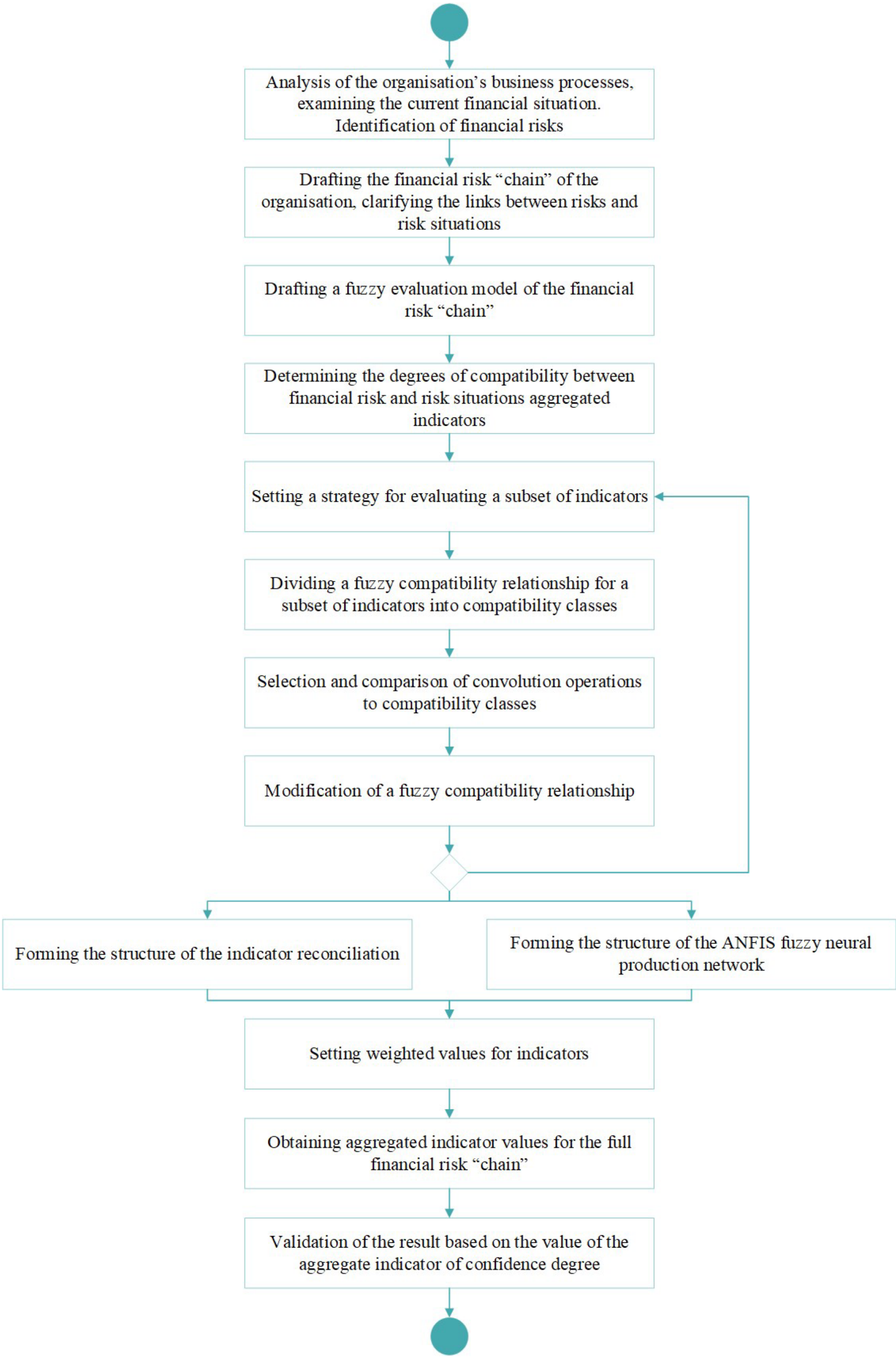

Fig. 5. **UML diagram of the generalised algorithm for a direct fuzzy evaluation methodology for an organisation's financial risk "chain"**

Source: compiled by the authors.

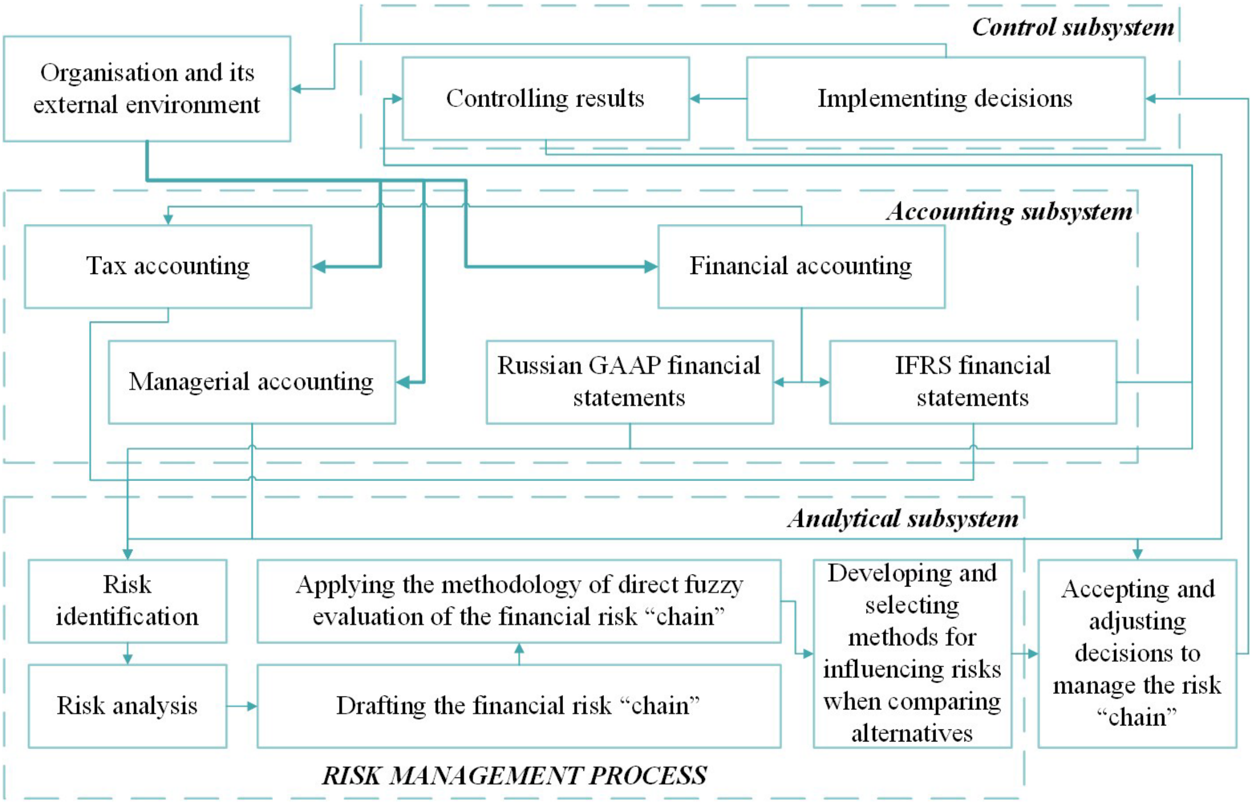

Fig. 6. **Formation of information flows in the process of evaluating an organisation's financial risk "chain" based on the proposed methodology of direct fuzzy evaluation**

Source: compiled by the authors.

business processes and a generalized "chain" of risks of an organization, allows taking into account the strategic aspects of the impact of financial risks on the activities of an organization and includes the stages shown in *Fig. 5*.

RESULTS AND DISCUSSIONS

The proposed method of direct fuzzy evaluation of the financial risk chain of an organization is focused on the conditions of increasing instability, uncertainty, complexity, and ambiguity of the current economic and political situation. For the timely identification of emerging or predicted financial risks, it is advisable to include it in the organization's information flow formation system in the process of risk management, in which risks are identified on the basis of the organization's tax, financial and management accounting (*Fig. 6*).

As confirmation of the practical significance of the proposed methodology, let us consider the evaluation of the financial risk "chain" of Macy's, Inc. Baseline data obtained from the Bloomberg based on the consensus forecast of the main economic indicators and historical observations for 2017–2021. To begin with, the cumulative average annual growth rate of each indicator was calculated using the formula (9):

$$CAGR_j = \sqrt[n]{\frac{V_t}{V_{t-n}}} - 1, \qquad (9)$$

where $CAGR_j$ — the cumulative average annual growth rate of the j-th indicator; V_t, V_{t-n} — historical values of the j-th indicator in years *t and* $t - n$.

Next, the predicted growth (forward growth, FG) of each j-th indicator was calculated. These two indicators were the starting point in the expert determination of the degree of probability of a particular risk (risk situation).

Based on the data on the consensus forecast, the average value of the consensus

Table 2

Consensus forecast of Macy's economic indicators

Metrics	$CAGR_j$, %	FG_j, %	$\bar{x}_j$	$me(x_j)$	σ_j	RSD_j, %	CL, %
Shopping capacity	−3.4	−3.6	109 226.20 sq. foot	110 526.00 sq. foot	2755.63 sq. foot	2.5	96.30
Net sales	−9.4	36.2	$ 23 622.00 million	$ 23 758.50 million	$ 415.47 million	1.8	97.70
Tax expenses	−25.5	−139.6	$ 334.85 million	$ 344.21 million	$ 27.33 million	8.2	89.04
EBITDA	−55.0	2203.5	$ 2695.11 million	$ 2688.00 million	$ 56.70 million	2.1	97.60
Cash and cash equivalents	6.7	22.5	$ 2055.99 million	$ 1796.89 million	$ 1320.65 million	64.2	23.20
Intangible assets	−3.2	14.4	$ 500.08 million	$ 471.97 million	$ 82.09 million	16.4	78.00
Accounts payable	−0.2	13.0	$ 3308.32 million	$ 3509.51 million	$ 580.38 million	17.5	76.40
Cash flow from operating activities	−22.5	232.6	$ 2158.87 million	$ 1883.62 million	$ 1162.27 million	53.8	33.40
CAPEX	−15.5	44.6	−$ 673.67 million	−$ 650.00 million	$ 40.16 million	6.0	90.50
Dividends paid	−28.9	−18.3	−$ 95.58 million	−$ 95.49 million	$ 0.50 million	0.5	99.40
Net change in cash	52.7	−66.0	$ 347.49 million	–	–	21.4	78.60
Current liquidity ratio	−4.0	2.9	1.19	–	–	15.1	84.90
Quick liquidity ratio	8.8	4.5	0.33	–	–	39.2	60.80
Debt to equity ratio	13.4	−32.5	4.01	–	–	13.9	86.10

Source: Bloomberg, authors' calculations.

forecast, the median, and the standard deviation (standard deviation, SD), the level of confidence in the forecast was calculated, and adjusted for the tendency to a normal distribution of forecast valuesusing formula (10). The first part of the formula represents the accuracy of the forecast in terms of the coefficient of variation, the larger the coefficient of variation, the lower the reliability of the forecast, so the value (1 — *RSD*) is applied, and *RSD* is the coefficient of variation. The second part of the formula reflects the correction for the tendency to the normal distribution law, from the inequality of the median and the average consensus value we get the desired correction — correct due to the equality of these values in the case of a normal distribution.

$$CL = \left(1 - \left|\frac{\sigma_j}{\bar{x}_j}\right|\right) - \left|\frac{me(x_j)}{\bar{x}_j} - 1\right|, \qquad (10)$$

Table 3

Identified financial risks of Macy's

Notation	Risk	Description of the prerequisite space	Description of the conclusion space	Risk value	Confidence degree
r_1	Risk of curtailing outlets	–	r_2	0.036	0.963
r_2	Risk of decline in business and consumer activity	r_1	r_4, r_6, r_7, r_{13}	0.001	0.977
r_3	Tax risk	–	r_4, r_5, r_6, r_{13}	0.001	0.890
r_4	Risk of no economic profit	$r_1 - r_3, r_5 - r_{14}$	r_{15}	0.001	0.976
r_5	Funding risk	r_3, r_6, r_7, r_{13}	$r_4, r_9, r_{11}, r_{13}, r_{14}$	0.001	0.232
r_6	Cash flow risk	r_2, r_3, r_{13}	r_4, r_5, r_{12}	0.481	0.786
r_7	Risk of diversion of funds from operating activities	r_2	r_4, r_5	0.083	0.598
r_8	Risk of reduced business innovation	–	r_4, r_{13}	0.001	0.780
r_9	Financial stability risk	r_5	r_4, r_{10}	0.007	0.861
r_{10}	Risk of financial dependence	r_9	r_4, r_{15}	0.234	0.861
r_{11}	Default risk	r_5	r_4	0.001	0.608
r_{12}	Risk of decrease in current liquidity	r_6	r_4	0.012	0.849
r_{13}	Risk of decrease in return on core activities	$r_1, r_2, r_3, r_5, r_8, r_{14}$	r_4, r_5, r_6	0.001	0.334
r_{14}	Risk of obsolescence of fixed assets	r_5	r_4	0.001	0.905
r_{15}	Risk of reduced investment attractiveness	r_4, r_{10}	–	0.183	0.994

Source: compiled by the authors.

where CL — the level of confidence in the consensus forecast; $\bar{x}_j$ — the consensus means of the j-th indicator; σ_j — the standard deviation of the predicted values of the j-th indicator from $\bar{x}_j$; $me(x_j)$ — the consensus median of the j-th indicator.

Formula (11) was used to determine the level of confidence in the coefficients and the indicator "Net change in cash" (11).

$$CL = 1 - \left(\sqrt[i]{\prod_{i=1}^{N} \left(1 + RSD_j\right)_i} - 1 \right), \tag{11}$$

where RSD_j — the coefficient of variation of the j-th indicator included in the model for calculating the indicator under study; i — the number of j-th indicators included in the model for calculating the indicator under study.

Table 2 presents the calculated indicators.

To calculate the value of the financial dependence risk indicator, we use formula (12).

$$r = \frac{V_{Fwd}}{\overline{V_i}} - 1, \tag{12}$$

where r — the value of the financial dependence risk indicator; V_{Fwd} — the forecast value of the *D/E* indicator; $\overline{V_i}$ — the average value of the *D/E* indicator for the last *i* periods (years).

In accordance with the methodology, the calculated initial data are presented in *Table 3*.

The prerequisites and conclusion spaces given in *Table 3* form a financial risks "chain" of this organization. Based on the available data, it is possible to calculate the probability index for the occurrence of a complete "chain" of risks using formulas (5)–(8), for this "chain" it has a value of 0.042 (4.2%), as well as an aggregate confidence degree indicator — 0.749 (74.9%). It seems possible to calculate the additional effect of the total risk both for individual decomposition levels of the Macy's fuzzy evaluation model of the financial risk chain, and for the entire "chain" using formula (13). However, the implementation of these calculations requires an internal audit of the organization's business processes and a professional assessment of losses from possible risks, taking into account the risk management strategy chosen by the organization.

$$M_{i,j} = \sum_{i=1}^{N} \sum_{j=1}^{N} R_{i,j} \left(A_{i,j}^{init} A_{i,j}^{\text{end}} \right), \tag{13}$$

where $M_{i,j}$ — the added effect of the total risk characterizing the costs associated with managing the j-th risk at the i-th decomposition level of the fuzzy evaluation model of the financial risk chain ($M_{0,1}$ — the added effect of the total risk of the full financial risk "chains"); $R_{i,j}$ — an aggregated fuzzy indicator that characterizes the significance of this risk in the financial risk "chain" obtained by formula (5); $\left(A_{i,j}^{\text{init}} - A_{i,j}^{\text{end}} \right)$ — a change in the structure of the financial risk "chain" when considering alternatives to each risk indicator or risk situation in order to find the best solutions that provide an acceptable value of the aggregate value of the indicator for the considered "chains" of financial risks in order to implement the risk management strategy.

Accordingly, the values obtained using the proposed method of direct fuzzy evaluation of the financial risk "chain" allow us to draw the following conclusion. Macy's in the current environment is threatened by the emergence and realization of risk situations of a financial risk "chain", accompanied by a cumulative effect leading to serious losses for Macy's, with a probability of 4.2% and a confidence degree of 74.9%. However, in order to conduct effective risk management, it is necessary to constantly monitor emerging risks based on a dynamic approach.

In the future, the development of the proposed methodology is the creation of an application software product that implements the main stages of the methodology based on the Python programming language, and its integration into the information system of the organization. In addition, it is advisable to develop software for monitoring emerging risks and compiling economically justified prerequisites and conclusion spaces based on the identified risks.

CONCLUSION

In modern conditions, specialists involved in risk management in organizations, when building models and forecasts, and mathematical descriptions of risk situations, should also rely on a dynamic approach, among the many factors of which a significant place is given to the time factor. Moreover, it is often difficult for the top managers of organizations to provide the analyzed risks with an objective quantitative assessment for the purpose of subsequent economic and mathematical modeling and forecasting. These circumstances affect the quality of managerial decisions. Particular attention should be paid to assessing financial risks, including changes in the purchasing power of money, inflationary expectations, investment turbulence, variability in the organizational structure, and the business model being implemented.

The proposed method of direct fuzzy evaluation of the financial risk "chain" is aimed at solving the above problems with the proper level of expert assessments of emerging risks, constant monitoring of the current financial condition, competent compilation prerequisites and conclusion spaces, and the correct choice of risk management strategy allows accurately assessing the threat of a certain "chains" of risks and losses from the implementation of specific risk situations for any organization in the context of dynamic changes in the internal and external elements of the business environment. The advantage of the described technique is the comparability of high estimation accuracy with low labor and time costs for modeling in systematic and comprehensive analysis. The methodology will allow organizations to more effectively and adaptively plan the risk management process, which will significantly increase the organization's resilience in a turbulent environment and remain focused on creating economic added value. The described methodology is a management decision support tool that allows to comprehensively study the financial and economic aspects of the functioning of the organization, and develop a corporate strategy, taking into account the diagnosis and optimization of risks and risk situations.

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L.V. Fomchenkova — problem statement, development of the theoretical and conceptual framework of the paper.
P.S. Kharlamov — development of the methodology of the direct fuzzy evaluation of financial risk "chain" of an organisation, graphical presentation of the results.
K.S. Melikhov — drafting the financial risk "chain" of an organisation, tabular presentation and description of the results, formation of conclusions of the research and abstract of the paper.

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