Application of Multi-Criteria Assessment in Banking Risk Management

Vladimir Ristanović[*]
Dinko Primorac[**]
Mihaela Mikić[***+]

Abstract: *Banks face a number of business risks on a daily basis. Today, operational risk is dominant. The aim of this paper is to develop a decision-making system when choosing a method of operational risk management by using the Analytical Hierarchy Process (the AHP method) and the Fuzzy Analytic Hierarchy Process (the FAHP method). Analytical hierarchical process is a simple efficient process in solving decision-making problems. The final decision depends on the assessment of a set of alternatives and the decision criteria. The main purpose of the process is to find appropriate solutions for defined user factors in the current competitive environment. The results obtained by the classical AHP method, as well as the FAHP method, show that external factors are the dominant criterion, especially during the financial crisis or the Covid19 pandemic, and that solutions should be sought in international standards, using control tools created by the banks themselves.*

*Keywords***:** operational risk; AHP/FAHP methods; decision-making

JEL Classification: C63, G32, E58

Introduction

While the banks are focused on financial risk management systems, such as credit risk, foreign exchange risk, interest rate risk, and market risk, recently they have started facing a problem regarding operational risk. Although the operational risk is not a recent one, with the outbreak of the global financial crisis in 2008, it has

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[*] Institute of European Studies, Belgrade, Serbia.

[**] Department of Economy, University North Croatia, Varaždin, Croatia.

[***] University of Zagreb Faculty of Economics and Business, Zagreb, Croatia.

[+] Mihaela Mikić is corresponding author. E-mail: mmikic@efzg.hr

become the dominant risk in banking. Up to now, the losses of the entire financial sector due to operational risk have been increasing steadily and are estimated at billions of dollars. The negative results of the banks have been largely affected their balance sheets as well. Disorders of financial flows have spilled over into commodity flows, which consequently brought the whole world into great financial uncertainty.

Operational risk is the risk that arises as the result of failures in the work of employees, inadequate procedures and processes in a bank, inadequate information management and other systems in a bank, as well as due to unforeseen external events (terrorism, crime, natural disasters, pandemics, cyber-attacks, crises). This risk negatively affects financial results and the capital of a bank to a greater extent than it might have seemed at first glance when analysing economic and quantitative indicators of banks, such as Return on Equity (ROE), Return on Assets Ratio (ROA), assets, etc.

Operational risk management implies managing the organization of work and operations, human resources, and technical support in a bank while respecting high standards, applicable regulations, and the adopted business practice.

Globally, the financial sector is facing the problem since there is no standard framework for operational risk management. Each financial institution needs to form a specific framework appropriate to its operating environment. It does not necessarily have to meet the Basel Criteria entirely, but it must reflect the culture of operational risk behaviour and operational risk management. Within this framework, the procedures should be defined, as should the guidelines designed regarding risk measuring and self-assessment, and they should test the effectiveness of the conducted control. The management ought to provide appropriate information and submit it in a timely manner and in an appropriate format for risk analysis. This should be followed by an analysis of measures and instruments for its mitigation and risk management. This process fully corresponds to the multi-criteria decision-making process and the structure of the AHP method. To confirm the reliability of the results, we also use the FAHP method.

We opted for the AHP method because it allows the assessment of either objective or subjective considerations, even quantitative or qualitative information. The structure of the AHP method supports different levels of detail about the main goal, tailoring a number of criteria and alternatives. In this way, an overview of the problem can be easily presented. AHP is often used in combination with other methods where authors use AHP to estimate the weight of the criteria (Stević et al., 2015). The purpose of multi-criteria assessment, in the AHP method, is that a bank precisely defines the problem - operational risk identification. This is followed by operational risk assessment - the extent of the risk, the manner and the cost by which such risks can be mitigated; and the assessment of whether the acceptance of the residual risk is consistent with the bank's strategy. Finally, when there is operational risk, bankers should strengthen their defence against operational risk by investing appropriately in

technology, data, and analytics. The preparation of control and monitoring, such as stress tests and/or recovery planning, is also crucial.

The advantage of applying the FAHP method is reflected in the possibility of developing different scales of comparison based on fuzzy triangular numbers. Such a change in relation to the classical AHP method, with an insufficiently large scale of comparison, provides an opportunity for the decision-maker to more easily assess the importance of a criterion or alternative, and to soften his subjectivity in solving this problem.

The structure of the paper is as follows. After the introduction, Section II presents, in brief, operational risk. Section III provides an explanation of the AHP method and FAHP method, along with a literature review. The methodology is presented in detail in Section IV along with the modelling of decision problems. Section V presents the results of the research in which the solutions are presented as the final decisions of the banks' management in the process of operational risk management. The last section offers concluding remarks.

Operational risk

International standards, viewed through the spectrum of Basel II standards, place emphasis regarding banking operations on the analysis of the effects of operational risk. The standards unequivocally state that operational risks along with credit and market risks present the basis for determining bank's total risk. The Basel Committee defines operational risk as "the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events". It could be said that this is the definition of operational risk in a broader sense since it covers numerous non-financial risks, including fraud, cyber, suppliers, behaviour, privacy, illegal trading, information security, etc. The Committee singles out specific principles for operational risk management in line with healthcare industry practice. More effective operational risk management is supported through the "three lines of defense" model known in the literature. The model consists of business line management, an independent corporate operational risk management function and independent review. The goal of applying the model is to form operational management that would identify risks by business lines, create a framework of operational risk in the bank and ensure independent review and control. (Luburić, 2017; BIS, 2011).

Modern banking has shown that operational risk should take an important place in the risk management agenda of banks (Neifar and Jarboui, 2018). Losses are significant, and future risks are increasing. Therefore, it is not surprising that supervisors require banks to bring operational risk under control and improve operational risk management methods (Barakat and Hussainey, 2013). The experience shows that

banks are ready to improve risk management. Most of them have already taken action in this direction with positive outcomes and results (see also, Cristea, 2021).

Modern banking flows accompanied by numerous crises, unstable financial markets and constant political pressures have directed the old perceptions and behaviour towards the risk to changes. In fact, they have been constantly changing, but to a greater extent in the last decade. Over the last years rising costs, as the result of the greater impact of operational risk, have made bank management concerned about operational risk management. Outdated operational risk management systems are being replaced by a new risk management methodology along with new sophisticated operational risk management systems.

It is crucial that banks develop an effective operational risk management framework with which organizational goals and superior performance can be achieved. For example, adequate operational risk management can accelerate the development of new initiatives. Simultaneously, international standards impose a new dimension. Through the Capital Accord, the Basel Committee imposed the obligation to banks to allocate regulatory capital for development, which specifies the minimum level of required capital for regulatory measures. The Supervisory Committee emphasizes the need to calculate the capital based on its own risk management techniques in banking activities. This strengthens the practice of operational risk management within a competitive environment (see also, Županović, 2014; Lu, 2013; Negrilă, 2009).

The Basel Committee provides the guidelines indicating the precautionary measures that banks should take. At the same time, regulatory guidelines for states are taken as recommendations, which the economy has to/can follow. Therefore, risk and capital management present the basis for improving the growth and profitability of banks or financial institutions. The regulatory defined amount of the required capital that banks need to have should not be viewed as a requirement, but as a basis for improving risk management practices. Banks invest significant resources in improving their internal risk processes, data infrastructure, and analytical capabilities (BIS, 2011).

Essentially, banks are recommended to manage operational risk management in stages as well. Adequate preventive activities can significantly reduce the impact of external and internal factors, but also mitigate the negative effects that operational risk causes. Planned activities should be conducted within the framework of banks' behaviour model in the situation of operational risk. In the second phase, the operational risk identification phase, it is necessary to set adequate operational risk recognition indicators. It is necessary to timely identify operational risk and intervene with adequate tools (depending on the banking product, users of banking services, and third parties) to mitigate the negative effects and consequences on the bank's operations. The last phase, which is time-limited, implies the implementation of the activities aimed at mitigating and reducing the risk of banks' behaviour. It is essential to act quickly, with adequate measures and instruments, since we are talking about

the phase in which it is evident that a risk with negative consequences has occurred. During all the phases, it is necessary to maintain control and perform the audit of operational risk assessment in accordance with the risk framework, complying with the regulations and internal audit reports (see also, Türsoy, 2018).

Literature Review

Knowledge about AHP

Although the most important measures for assessing the sustainability of financial institutions are considered to be financial measures, the paper will now focus on other, indirect effects on banks' financial results. Based on the use of multiple criteria analysis, a framework will be proposed through which potential criteria for assessing the existence of operational risk and alternatives for operational risk management will be selected. The essence of the AHP method is reflected in a greater degree of objectivity, which reduces the importance of making decisions based on subjective feeling. It is effectively applicable in complex situations and simplifies the decision-making process.

Numerous analytical processes and systems are used for making decisions within organizations. Furthermore, by using multi-criteria models Zopounidis and Doumpos (2002, 2003), Steuer and Na (2003), Spronk et al. (2005), Nasrallah and Kavasmeh (2009) provide the support for making decisions within the banking sector - financial planning, bankruptcy assessment, credit risk assessment, stock classification, the choice of financial instruments, bank/banking product rating, interest rate choice, business risk analysis, etc. Moreover, the AHP method is one of the most commonly used multi-criteria decision-making models. It is designed to solve simple problems with multiple criteria. It allows individuals or teams to make good assessment of isolated problems within organizations. While doing so, the technique of the AHP method for organizing and analysing complex decisions is based on the combined application of mathematics and psychology. It is widely used in group decision-making and in various decision-making situations (industry, business, health, employment, job creation, education, etc.).

Recently, the use of various methods of job evaluation has been growing. Saaty's AHP method, which is used to solve problems with multiple decision-making criteria, has been seeing increasing use (Saaty, 2000). The basis of the model is to make the best decision according to the set criteria. The application of the model is widespread and exists in almost all branches of the economy.

Specifically, the AHP method is realized in three steps. Firstly, a hierarchical structure of the problem is created. Afterwards, a pairwise comparison between the elements/alternative decisions is made. Finally, the synthesis of priorities is conducted

(Saaty, 2008a). The structure of the model consists of a general problem, a group of options or alternatives for achieving the goal, and a group of factors or criteria that connects the alternatives with the goal. A deeper analysis is also possible when the criteria are divided into sub-criteria at as many levels as the problem requires. The advantage of the AHP method is that it can be designed depending on the existing problem, as well as on the knowledge, assessments, values, opinions, needs, or desires of participants in the decision-making process (Kyaw and Kyi, 2014). According to Leung et al. (2006), the advantage of the AHP method is reflected in the fact that it can be easily adapted to specific situations, overcoming some traditional problems of subjective versus objective measures.

Literature examples about AHP

Spiridakos (2001) conducted a multi-criteria evaluation of jobs in a large company, and Dagdeviren (2004) used AHP to evaluate various jobs in the power industry, while Erarslan et al. al. (2013) used it for job evaluation in a steel company. In the field of finance, Butterworth (1989) used the multiple-decision model when making a decision to relocate the bank's headquarters. Kauko (2007) suggested the use of the AHP method to rank a bank's location attributes, while Bergendahl and Lindblom (2008) pointed to the importance of the model when considering locating a bank according to its business activity. Kyaw and Kyi (2014) used the AHP method as a useful tool for job-seeking, developing a decision-making system for a job-seeking process. The application of the AHP method in health care, an effective tool to support decision-making in this field, was demonstrated by Schmidt et al (2014) and Liberatore et al. (2015). Jurik and Sakal (2015) used the AHP method in the field of human resource management, where they used this method for employee selection as well as assessment and competencies of managers.

Knowledge FAHP

The main disadvantage of the classical AHP method is the insufficiently large comparison scale. This shortcoming is remedied by the FAHP method. Using this method, different comparison scales based on obscure triangular numbers have been developed. This approach allows decision-makers to assess the importance of criteria or alternatives much more closely and more easily. The main advantage of FAHP over classical AHP is that the subjectivity present in solving these problems is successfully minimized.

Literature examples about FAHP

During the last few decades, there have been several approaches to FAHP proposed by various authors. Van Laarhoven and Pedricz (1983) proposed one of the earliest methods of AHP. They used the fuzzy numbers with triangular membership functions that described the fuzzy comparative judgments. On the other hand, Buckley (1985) revealed the fuzzy priorities for comparing relations using trapezoidal membership functions. A few years later, Boender et al. (1989) developed a more robust approach to the normalization of local priorities by extending the aforementioned Van Laarhoven and Pedricz method. Finally, Chang (1996) proposed a new method with the use of triangular fuzzy numbers. Simultaneously, he implemented both extent analysis method for the pairwise comparison scale of AHP and the synthetic extent values of the pairwise comparisons. Mikhailov (2000) proposed a new Fuzzy Programming Method, based on a geometrical representation of the prioritization process. Enea and Piazza (2004) presented an implementation of FAHP method where more certain and reliable results can be achieved by considering all the information derived from the constraints. Kahraman (2008) offered researches of the most important FAHP methods, giving a numerical example for each one. Seçme et al. (2009) proposed a fuzzy multi-criteria decision model to assess the banks' performances in Turkey. Yang (2009) proposed a logarithm triangular FAHP method to analyse the efficiency and advantages of supply chain.

Methodology

AHP method

Analytical hierarchical processes (*AHP method*) have been used for almost five decades in multi-criteria decision-making tasks. It has been applied in the decision-making process on numerous issues as well as for solving various complex tasks. This method was created by American mathematician Saaty (1980) and ever since has been effectively applied in a number of areas and has become one of the most used decision-making method tools.

Within the hierarchical structure of the AHP method until the final result and the right outcome for decision-making, it is necessary to start by pairwise comparison of the elements and evaluation of their mutual significance. For this purpose, Saaty's scale of relative importance is used, in the following form:

Table 1: Saaty's scale of relative importance

Intensity of importance	Definition	Explanation
1	Equally important	Two activities contribute equally to the objective
3	Weak importance	Experience and judgement slightly favour one activity over another
5	Strong importance	Experience and judgement strongly favour one activity over another
7	Demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	

Source: Saaty (2008b); Saaty and Vargas (2006)

The application of the Saaty scale of relative importance is a key tool in the decision-making process, as it provides a greater number of possibilities. In this way, through the analysis of the elements (criteria and alternatives) within the hierarchical structure of the AHP method of pairwise comparison, it compensates for the existence of potential decision-makers' uncertainty. Actually, uncertainty is reduced due to minor changes in decision-makers' assessments. The obtained values, in the following iteration, form the elements of the corresponding comparison matrix (matrix A). In order to obtain each element of the matrix (a_{ij}) we use Saaty's scale of pairwise comparison of n elements, by comparing the elements of the lower hierarchical level with the elements of the immediately higher hierarchical level (the measure of this comparison is the indicator of the importance of the element *i; i = 1, 2, …, n*, and the element *j; j = 1, 2, ..., n*).

Observed by methodological structure, the AHP method is a hierarchically structured decision-making model. The model consists of three or more hierarchical levels, depending on the purpose of the analysis. These are the goal, criteria and alternatives (Figure 1). The goal is always at the top of the hierarchical structure. The rule is not to compare the goal with the other elements in the hierarchical structure. The comparison starts at the first structural level, i.e. with criteria. They are compared in pairs (each with each other) with the first superior element at a higher level. By comparing pairs, alternatives are evaluated, comparing each of them. This creates a hierarchical presentation of the problem through which the solutions to the problem are defined. Respecting the mathematical rules and the order in the mathematical sequence, all numerical values are entered into the matrix. As a rule, the diagonal matrix has the value of 1, in the upper part of the matrix above the diagonal the values are entered, while in the lower part of the matrix below the diagonal their reciprocal values are entered. To make pairwise comparison of the elements, the method of eigenvalues is used, by which the weight vectors of the entered elements are determined through a linear system (equation 1):

$$A * \omega = \lambda * \omega, \quad _{e^T=1} \tag{1}$$

where A is the comparison matrix of the dimension nxn, ω the eigenvalue vector, λ the eigenvalue, and e is the unit vector.

Using the distributive aggregation model, weight vectors are synthesised, followed by assessing the consistency rate and index.

$$Consistency\ Index = \frac{(\lambda max - n)}{(n-1)} \tag{2}$$

$$Consistency\ Rate = \frac{Consistency\ Index}{Random\ Index} \tag{3}$$

where RI is the random index (matrix consistency index of n randomly generated pair comparisons). Calculated values of the random index are presented in Table 2 (Saaty, 1980).

Table 2: The values of the random index (RI)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
R.I.	0	0	0.58	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.51	1.48	1.56	1.57

In the next step, the synthesis of local priority vectors is performed by applying a distributed data aggregation model (Saaty, 1980). Afterwards, the consistency of the obtained vector values is examined. The consistency of the evaluation is checked by the degree of consistency, i.e. by using CR parameter, for which the limit value is defined at 0.1 level. When the degree of consistency is higher than 0.1, it is necessary to repeat the evaluation of the vector in the matrix. To put it differently, it is necessary to repeat the comparison of the rule by the eigenvalues method. By ranking the final values of the consistency index, a solution to the decision problem is obtained.

Modelling of decision-making problem by AHP method

Generally speaking, the AHP method enables individual and group decision-making, and implies the analysis of decision-making problems through several hierarchical levels. The usual hierarchical structure of the AHP method is presented in Figure 1.

Figure 1: Structure of the decision-making problem in a hierarchy
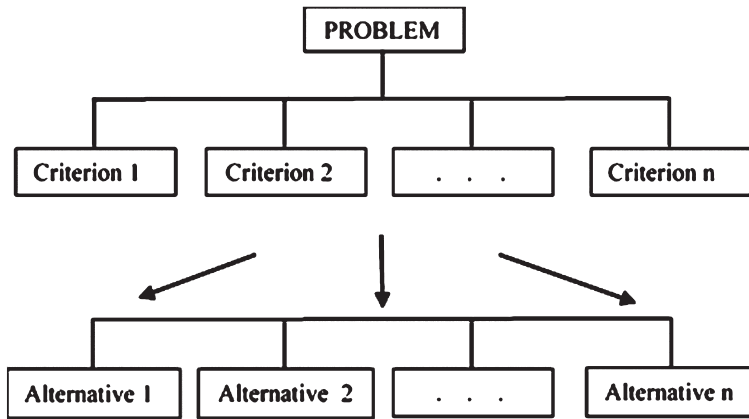
Source: Kyaw and Kyi (2014)

Modelling in the AHP method begins with the creation of an overall hierarchical structure. The first step is to define the problem. Afterwards, a comparison of all the elements of the same level of hierarchy in relation to the elements from a higher hierarchical level is performed. In our example, at the top of the hierarchical structure there is a problem faced by banking sector - operational risk. The question is how to manage operational risk. In accordance with the set problem of the AHP method, the criteria are defined which clearly identify the problem, i.e. operational risk. The following criteria were singled out: C1 - Inadequate Infrastructure, C2 - Human Resources, C3 - External Factors, and C4 - System Events. The results are obtained from several predetermined alternatives which represent the options for solving the problem: A1 - Technology, Data and Analytics, A2 – Supervision Elements, and A3 - International Standards. The final decision is made on the basis of the highest rank, and that is the best solution to the defined problem.

Good operational risk management implies an adequate framework in which banks can identify, measure, and mitigate operational risk. In this way, we can measure, how much the bank is prone to risk and the bank's responsibility, after which special plans for managing the bank's operational risk can be developed. The bank's propensity to operational risk should be low. It is not easy to identify and understand operational risk (behaviour, fraud, cyber, external factors, etc.). Therefore, we define adequate criteria based on which we can measure the harmful consequences for the reputation, liquidity, and the bank's capital. Solutions should be sought through the best alternative, such as precisely defined technology, data and analytics, international standards, and independent banking tools (Heurtas, 2016).

It is important to emphasize that the bank management should not view operational risk through the regulatory framework, but through a hierarchical structure within

which all operational risk criteria and solutions for operational risk management will be analysed. This provides the space to improve the competitiveness and performance of the bank. Otherwise, operational risk management will be made more difficult and the business operation costs more.

FAHP method

Fuzzy Analytical hierarchical processes (*FAHP method*) shows that by considering all available information arising from constraints, better results in terms of certainty and reliability can be achieved. One of the key questions on the implementation of any fuzzy programming is the choice of fuzzy numbers. A triangular fuzzy number Ã is fully characterized by the triple of real numbers (l, m, u), where $l < m < u$, where the parameter m gives the maximal grade of the membership function $\mu_{\tilde{A}}(x)$ (i.e., $\mu_{\tilde{A}}(m) = 1$), and the parameters l and u are the lower and the upper bounds of the field of the possible evaluations.

We also need to compare the chosen criteria. The next step is to create a pair-wise comparison matrix. This matrix is created with help of scale of relative importance (Table 3.). All numeric values from the scale of the classical AHP method are converted into fuzzy numbers.

The fuzzy number we can represent in the following form:

$$\mu \tilde{A}(x) = \tilde{A} = (1, 2, 3) \tag{4}$$

Table 3: Fuzzy scale of relative importance

Intensity of importance	Definition
(1, 1, 1)	Equally important
(2, 3, 4)	Weak importance
(4, 5, 6)	Strong importance
(6, 7, 8)	Demonstrated importance
(9, 9, 9)	Absolute importance
(1, 2, 3) (3, 4, 5) (5, 6, 7) (7, 8, 9)	Intermediate values

Fuzzification in FAHP method

Fuzzification is the process of decomposing a system input and/or output into one or more fuzzy sets. Many types of curves and tables can be used, but triangular-shaped membership functions are the most common, since they are easier to represent in embedded controllers. Also, it is a step to determine the degree to which an input data belongs to each of the appropriate fuzzy sets via the membership functions.

Figure 2: Triangular membership function
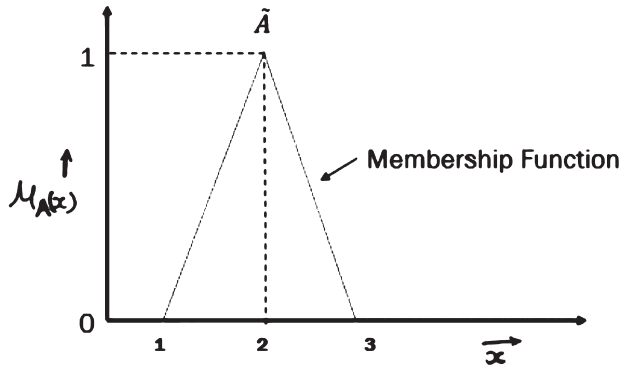
Source: Kannan et.al (2013)

We use linguistic variables to compare two evaluation criteria in a murky environment. Experts determined the values of the variables using triangular fuzzy numbers. Graph 1 shows a triangular membership function. The lower and upper limits of triangular fuzzy numbers (one and three) represent an uncertain range that could exist in the preferences expressed by the decision-maker.

In the following steps we used the geometrical mean to calculate weights. Next, we calculate the fuzzy geometric mean value. Equation (5) presents the example of two fuzzy number:

$$\tilde{A}_1 \, x \, \tilde{A}_2 = (l_1, m_1, u_1) \, x \, (l_2, m_2, u_2) = (l_1 x l_2, m_1 x m_2, u_1 x u_2) \tag{5}$$

It can be seen from equation (5) that lower point is multiplied with lower point, middle point with middle point, and upper point with upper point. So, we calculate the multiplied fuzzy number. Now we can calculate the fuzzy geometrical mean value. Finally, fuzzy weights will be calculated by multiplying the inversion values of the fuzzy geometric mean values and the sum of the lower/middle/upper values of each criterion (equation 6).

$$\tilde{\omega}_i = \check{r}_i \, x \, (\check{r}_1, \check{r}_2, \dots \check{r}_n)^{-1} \tag{6}$$

where $\hat{\omega}_i$ is fuzzy weights, and $\check{r}_i$ fuzzy geometrical mean values.

Results of the application of the methods

The evaluation of the criteria and variants was conducted by two experts in the field of economics, banking and finance, professors and lecturers, with relevant references

in this field. For a wider research, other experts could be included, such as the ones covering other indicators related to the education of service users, digitalization of banking operations, as well as broader social aspect of employees. Representatives of financial associations, non-governmental sector and businessmen could also make a significant contribution to the decision-making process.

Firstly, the analysis was initiated by defining a goal. With such a defined goal, according to the AHP method, the decision-makers compared the criteria with the set goal. By defining the criteria, they also defined the alternatives within the hierarchical structure of the model. To select the best means/tools for operational risk management, the comparison of 3 alternatives was conducted, based on 4 criteria. The next phase regarding the choice of means/tools for managing the application of the AHP method was the development of the hierarchy of the problem. The evaluation of the criteria was the next step, within which the above-mentioned Saaty's nine-point scale was applied. The criteria were evaluated aiming to define the weight coefficients required for the estimation of the work, method or tools of operational risk management. In the fifth phase, the alternatives were evaluated on the basis of each criterion, i.e. each of the 3 alternatives were evaluated based on the 4 considered decision criteria. Thus, each alternative gained its own value. In the final phase, a decision and the choice of variants were made. The alternative that had the highest degree of value would be the most favourable solution for the bank in the process of operational risk management.

The decision-makers had the task to single out the criteria, make pairwise comparison of the criteria in relation to the goal (using the Saaty's scale), and then compare the variants in pairs in relation to each criterion.

Table 4: Matrix of comparison of criteria and computed weights in AHP method

GOAL	C_1	C_2	C_3	C_4	Wi
C_1	1	1/3	1/3	1	*0.122*
C_2	3	1	1/3	3	*0.283*
C_3	3	3	1	3	*0.473*
C_4	1	1/3	1/3	1	*0.122*

Source: Authors calculation

Table 4 shows that the most important criterion for the banking sector is External Factors, followed by Human Factors, and, finally, two criteria with the same weight vector, Inadequate Infrastructure and Systemic Events. Pairwise comparison of the criteria within the matrix was performed. In order to avoid the errors in drawing conclusions while determining the value of the criteria, an assessment of the extent of deviations from the consistency was undertaken. After calculating the maximum value of the comparison matrix, λmax = 4.15, the consistency index (CI = 0.06) and the degree of consistency (CR = 0.05) were assessed. Since the value of the consistency

index was less than the limit value for consistency testing of 0.1, we could conclude that the comparison matrix had been set properly.

In the next step, the evaluation of the variants was performed according to each of the criteria taken into consideration individually. Table 5 presents the comparison matrix for the variants in relation to four criteria, with corresponding weight vectors.

Table 5: Decision-making matrices with respect to the criteria and computed weights in AHP method

C_1	A_1	A_2	A_3	W_i		C_3	A_1	A_2	A_3	W_i
A_1	1	1/3	1/2	0.16		A_1	1	1/3	1/3	0.14
A_2	3	1	2	0.54		A_2	3	1	1/2	0.33
A_3	2	½	1	0.30		A_3	3	2	1	0.53
C_2	A_1	A_2	A_3	W_i		C_4	A_1	A_2	A_3	W_i
A_1	1	1/4	1/3	0.12		A_1	1	3	2	0.54
A_2	4	1	2	0.56		A_2	1/3	1	1/2	0.16
A_3	3	1/2	1	0.32		A_3	1/2	2	1	0.30

Source: Authors calculation

The methodological concept of the AHP method implies that with the calculation of the priority of the criteria in relation to the set problem, and then the priority of the alternatives with respect to the criteria, the priorities of the alternatives in relation to the set problem can be calculated. The result of these calculations is computed weights for each level. Finally, at the very end of the procedure, an overall synthesis of the problem of choice was conducted. In the last step, the obtained results were ranked according to the size of the computed weight, which provided a solution for the best choice and decision-making by the bank in terms of operational risk management (Table 6). The alternative with the highest total weight received the highest value in the rank. Simultaneously, it was the final decision, that is, selecting the optimal way to manage operational risk.

Table 6: Total weight and the rank of variants in AHP method

GOAL	C_1	C_2	C_3	C_4	Rang
A_1	0.02	0.03	0.07	0.07	0.19
A_2	0.07	0.16	0.16	0.02	0.40
A_3	0.04	0.09	0.25	0.04	0.41
	0.13	0.28	0.46	0.13	1

Source: Authors calculation

The verification of the above steps was carried out through a table of all weight vectors. In the final table (Table 6), in the highlighted field the sum of all the values

for variants had to equal to 1. This is a confirmation that the procedure was method-ologically accurate and correct.

The final decision indicates that the acceptance of international standards and the application of adequate tools in identifying, mitigating, and, most importantly, elimi-nating of external operational risk factors are crucial for operational risk management in the banking sector. Nowadays, external factors, such as terrorism and criminal ac-tivity, natural disasters, economic crises, migration, pandemics, or cyber-attacks have the greatest impact on the occurrence and existence of operational risk, increasing the negative effects on the business results of the banking sector. In modern circumstances, when the influence of these factors is frequent, and very similar, the solution should be sought in internationally valid standards. This implies a change in regulations, ap-plication of accounting and other standards in accordance with the flows in banking operations and measures that should be made in operational risk management. The latter also refers to the recommendations that international institutions give to states and banks. The recommendations insist on creating your own tools, such as stress tests, early warning indicators, etc. Particular emphasis is placed on the need to plan recovery and solving of problems, then define the time for the implementation of all actions, as well as improving risk forecasting matrix. By including additional criteria and alterna-tives, it would be possible to examine bank operations in more detail in the conditions of the growing impact of operational risk with all negative consequences for banks.

To check our results, we calculated weights using FAHP method. We also started calculation by pairwise comparison of the criteria, then we used the geometrical mean to calculate fuzzy weights.

Table 7: Matrix of comparison of criteria and computed weights in FAHP method

GOAL	C_1	C_2	C_3	C_4	W_i
C_1	1,1,1	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1,1,1	*0.123*
C_2	2,3,4	1,1,1	1/4, 1/3, 1/2	2,3,4	*0.279*
C_3	2,3,4	2,3,4	1,1,1	2,3,4	*0.474*
C_4	1,1,1	1/4, 1/3, 1/2	1/4, 1/3, 1/2	1,1,1	*0.123*

Table 8: Decision-making matrices with respect to the criteria and fuzzy weights in FAHP method

C_1	A_1	A_2	A_3	W_i	C_3	A_1	A_2	A_3	W_i
A_1	1,1,1	1/4,1/3,1/2	1/3,1/2,1	*0.173*	A_1	1,1,1	1/4,1/3,1/2	1/4,1/3,1/2	*0.143*
A_2	2,3,4	1,1,1	1,2,3	*0.172*	A_2	2,3,4	1,1,1	1/3,1/2,1	*0.345*
A_3	1,2,3	1/3,1/2,1	1,1,1	*0.108*	A_3	2,3,4	1,2,3	1,1,1	*0.512*

C_2	A_1	A_2	A_3	W_i	C_4	A_1	A_2	A_3	W_i
A_1	1,1,1	1/5,1/4,1/3	1/4,1/3,1/2	*0.123*	A_1	1,1,1	2,3,4	1,2,3	*0.519*
A_2	3,4,5	1,1,1	1,2,3	*0.543*	A_2	1/4,1/3,1/2	1,1,1	1/3,1/2,1	*0.173*
A_3	2,3,4	1/3,1/2,1	1,1,1	*0.334*	A_3	1/3,1/2,1	1,2,3	1,1,1	*0.308*

Table 9: Total weight and the rank of variants in FAHP method

GOAL	C_1	C_2	C_3	C_4	Rang
A_1	0.021	0.034	0.068	0.064	0.187
A_2	0.064	0.152	0.164	0.021	0.401
A_3	0.038	0.093	0.223	0.038	0.412
	0.123	0.279	0.474	0.123	1

Source: Authors calculation

From the above tables and figures, we concluded that there is a small difference between the obscure numbers that describe the final scores obtained by the two methods. In fact, the results obtained using a limited FAHP method contain a lower level of uncertainty.

Concluding remarks

The application of the AHP method and the FAHP method in the structure of multi-criteria decision-making shows how the bank management can reach the best solution in the process of operational risk management. It has been once again confirmed that these methods are a useful tool in solving the problem of multi-criteria decision-making in the banking sector. Respecting the methodological concept, based on the separate opinion of the decision-maker, different types of importance of the selected criteria for the selection of operational risk indicators are ranked. The structure of these methods also provides the possibility for a more detailed analysis of the selected criteria, within which a more comprehensive analysis of all sub-criteria can be conducted.

The paper precisely defines the sets of criteria and alternatives within the hierarchical structure of the AHP method. The criteria are evaluated in relation to the defined goal, and in the next iteration the alternatives are evaluated in relation to the selected criteria. All computed weight vectors (of both criteria and alternatives) are within the limit values, also confirmed by the created square matrices. The final ranks are obtained based on the height of weight vectors. Finally, ranks enable the final decision. The results of the research have proved that the external factor indicator is the best ranked, and that the key solution is in international standards and recommendations for the development of own tools in the process of operational risk management. The results of the FAHP method confirmed the above criteria and their weight vectors, using a comparison scale based on triangular numbers.

We can conclude that operational risk deserves an important place in the risk management system of banks or any financial institutions. Although it does not directly affect banks' financial indicators, it indirectly leads to huge losses. The nature of operational risk is influenced by numerous external and internal factors with great financial consequences in the long run. This confirms the well-known "three lines of

defense" model in the literature in terms of more effective management of operational risk, where external factors, human resources, and system processes are highlighted as the central problems of operational risk. We have also seen that there is a strict control due to regulations and international standards imposed on states, both by supervisors and because of the demands of investors in the financial sector. This further reinforces the need for a stronger defence mechanism against operational risk.

As a future direction of the deeper analyses, other decision-making methods can be included to ensure more integrated and/or comparative study.

This type of analysis can represent a good basis for a more detailed investigation of business risk management in banks. At the same time, it can contribute to the introduction of new rules of conduct and the improvement of business culture, thus ensuring the sustainable success of central banks and other subjects of the financial system in dealing with banking risks.

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Conflicts of interest/Competing interests

There is no conflict of interest/Competing interests

Availability of data and material

Please contact the authors (primary research).

Code Availability

The computer program results are shared through the tables in the manuscript.

Authors' Contributions

Vladimir Ristanović: Methodology, Investigation, Writing – original draft.
Dinko Primorac: Conceptualization, Writing – review and editing, Project administration.
Mihaela Mikić: Writing – review and editing. Data curation, Methodology.

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Appendix

Flow Chart 1: The Analytic Hierarchy Process (AHP) algorithm
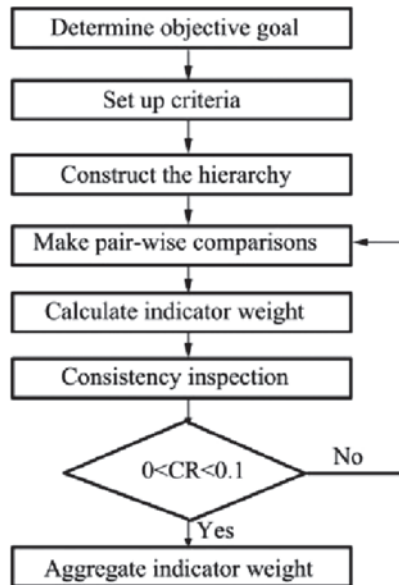
Flow Chart 2: The Fuzzy Analytic Hierarchy Process (FAHP) algorithm