BULLETIN of Cherkasy State Technological University

Journal homepage: https://bulletin-chstu.com.ua/en

Vol. 30 No. 2. 2025

UDC 004.056.5:351.862
DOI: 10.62660/bcstu/2.2025.44

Integrated method for assessing expert competence (IMAEC) in state information security

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Abstract. The relevance of this study is grounded in the need to improve methods for evaluating expert competence in the field of state information security. The increasing number of threats in cyberspace and the growing demands on specialist qualifications necessitate innovative decision-making approaches that can account for subjective factors and data uncertainty. This research aimed to develop and test an integrated approach combining the Analytic Hierarchy Process (AHP) with fuzzy logic for the assessment of candidates for expert positions in information security. The AHP enabled the problem to be structured as a hierarchical model encompassing the goal, criteria (experience, certifications, communication skills), and alternatives (candidates). The AHP methodology involved pairwise comparison of criteria, calculation of weights, and consistency checks of the matrices. Fuzzy logic complemented AHP by enabling the processing of imprecise data through fuzzification, the application of "If-Then" rules, and defuzzification. Practical validation of the method was carried out using the example of

Article's History: Received: 08.01.2025; Revised: 19.04.2025; Accepted: 16.06.2025.

Suggested Citation:
Prokopovych-Tkachenko, D., Rybalchenko, L., Zvieriev, V., Bushkov, V., & Khrushkov, B. (2025). Integrated method for assessing expert competence (IMAEC) in state information security. *Bulletin of Cherkasy State Technological University*, 30(2), 44-52. doi: 10.62660/bcstu/2.2025.44.

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candidate evaluation based on the specified criteria. The research findings demonstrated that the proposed approach enabled the integration of both precise and imprecise elements of assessment, thereby improving the accuracy and justification of decisions. The Monte Carlo method was employed to verify the model's reliability, ensuring result stability through repeated simulations of data variations. The results confirmed the method's high adaptability to handling uncertain data. The practical value of the study lies in the application of the integrated approach to enhance the efficiency of personnel selection – an essential component in safeguarding information security within state institutions. The proposed method may also be applied to other multi-criteria decision-making problems under conditions of uncertainty

Keywords: analytic hierarchy process; fuzzy logic; decision-making; criteria; fuzzification; defuzzification; Monte Carlo

INTRODUCTION

The assessment of expert competence in the field of information security is one of the critical tasks for ensuring the effective functioning of state institutions. The increasing number of cyberattacks and the development of complex technologies demand the involvement of qualified specialists who can rapidly adapt to emerging challenges. According to researcher D. Landoll (2021), the spread of hybrid threats – now a frequent occurrence in contemporary life – is influenced by the global digital environment, which necessitates reliable methods of protection. Various approaches exist for assessing risks in the field of information security. For example, the study by V.V. Yemelyanov *et al*. (2021) is based on traditional criteria such as formal qualifications, professional experience, and certification outcomes.

However, K. Latysh *et al*. (2022) argued that substantial errors may occur in the examination of information technology-related issues due to the use of outdated methods, obsolete logical protection tools for technical media, and flawed approaches to analysing past mistakes. In the academic study, I. Hasiuk & O. Ivanii (2024) observed that traditional criteria fail to consider adaptability to frequently changing threats and that their effectiveness in crisis situations is limited, as not all cyber incidents can be taken into account. The methodology proposed by K. Smith *et al*. (2023) for multi-criteria decisionmaking – namely, the AHP – is considered the most effective. It enables the structuring of tasks by dividing them into levels of objectives, criteria, and alternatives, and allows for pairwise comparison of criteria, determination of their relative weights, and calculation of consistency ratios.

Most existing methods for assessing experts are based on traditional approaches that consider only quantitative indicators, overlooking subjective factors such as professional intuition, adaptability, and the ability to operate under uncertainty. This results in limitations when forming an objective picture of a candidate's competence. The integration of new decision-making methods that account for both precise and imprecise aspects of evaluation is therefore of particular importance. Traditional approaches lack the flexibility required to handle incomplete or contradictory data, which is typical in the field of information security. Consequently, there is a need to implement combined methods that ensure objectivity, reliability, and a high degree of accuracy in expert assessment. The AHP is among the most effective methods for multi-criteria decision-making. It enables pairwise comparison of criteria, determination of their relative weights, and calculation of consistency ratios (Smith *et al*., 2023).

According to V.O. Burenko (2024), despite its numerous advantages, the classical AHP is not always effective when dealing with imprecise and subjective data, which is typical in the assessment of expert competence in the field of information security. To address this issue, researchers M. Averkyna & M. Prystupa (2019) considered the integration of AHP with fuzzy logic methods to be a promising solution. These methods enable the processing of uncertain and vague evaluations through the fuzzification of input data, the use of "If-Then" fuzzy rules, and defuzzification. Scholars N.I. Domantsevych & H.S. Shestopal (2023) noted that such an approach allows for the integration of both quantitative and qualitative aspects of expert evaluation, thereby enhancing the justification and accuracy of decisionmaking. Researcher I.M. Debela (2021) applied a Bayesian approach for assessing alternative decisions involving continuous random variables, which takes into account the properties of a holistic system as influenced by the surrounding environment. According to N. Fil & O. Kudyrko (2023), the application of a multi-criteria method for evaluating website quality enabled the development of a custom methodology for determining the significance coefficients of website quality criteria. The application of mathematical and statistical methods in modern business processes by researcher V. Havryliuk (2021) produced positive results in credit scoring models used to assess solvency. Scoring models are, in fact, among the tools used to evaluate leasing risks in banking and financial operations.

According to research by L. Petyk & B. Kravchenko (2024), the Monte Carlo method is additionally used to assess the stability of proposed approaches. This technique allows for the simulation of random data variations and the analysis of result reliability. It helps to minimise the influence of subjective factors and ensures the stability of final evaluations, even under conditions of significant variability in input parameters (IEC 31010:2019, 2019). Researchers A.F. Ayeni *et al*. (2020) described a methodology that combines AHP with fuzzy comprehensive evaluation (FCE) for risk analysis in the field of information security. Although their approach demonstrates high accuracy, it is less adaptable for competence assessment tasks due to the complexity of interpreting the results. In addition, the Monte Carlo method serves as an effective tool for testing the robustness of models that operate with random data variations. In this study, the author employed a multi-layered structure and introduced a rating matrix to describe the relationships between judgement factors. Based on calculations of the impact of these factors on security, a new quantitative risk assessment method has been developed. A method for analysing the results of fuzzy judgements was proposed. This method shifts the perspective on information security assessment from a "black box" approach and plays a role in verifying and adjusting outcomes derived from traditional models.

The use of a multi-layered structure and the introduction of a rating matrix by L. Wang *et al*. (2010) to describe the relationships between influencing factors enabled the development of a new quantitative method for risk assessment based on the calculated impact of these factors on security. The proposed method for analysing the results of fuzzy sets in the context of information security played a significant role in verifying and refining the outcomes generated by traditional models. In the study by V. Lukichov *et al*. (2023), a methodology, that accounts for the specific requirements of cybersecurity and employs multi-factor risk analysis, was developed, implemented, and tested. This approach, based on an integrated method, proved to be highly effective. Thus, the implementation of an integrated method combining the AHP, fuzzy logic, and the Monte Carlo method enables the development of an effective system for assessing expert competence in the field of information security. This study aimed to design, implement, and test such a methodology, taking into account the specific requirements of cybersecurity and the need for multi-factor risk analysis.

MATERIALS AND METHODS

The development of the Integrated method for assessing expert competence (IMAEC) was based on the use of two core algorithms: the AHP and fuzzy logic. The AHP structured the problem as a hierarchical model consisting of three levels: the goal (selecting the most suitable expert), the criteria (experience, certifications, and communication skills), and the alternatives (candidates). The process began with the construction of a pairwise comparison matrix to assess the relative importance of each criterion and alternative. Based on these data, eigenvectors and criterion weights were calculated, and the consistency of the matrix was evaluated using the consistency index and consistency ratio. If the level of consistency exceeded the acceptable threshold, the matrix was reviewed and adjusted accordingly.

The next stage involved the use of fuzzy logic, which allowed for the inclusion of subjective expert assessments in cases where data were imprecise or incomplete. Input data were fuzzified using membership functions – for instance, the "experience" criterion was divided into sets such as "low", "medium", and "high". Fuzzy "If-Then" rules enabled the aggregation of data, while defuzzification converted the results into precise values. To assess the reliability of the model, the Monte Carlo method was applied to simulate random variations in the input data. Hundreds of iterations with varying parameters were conducted, allowing for an evaluation of the stability of the results. The model demonstrated adaptability to change and maintained high accuracy, even in cases of significant variability in the input data.

RESULTS AND DISCUSSION

AHP. Step 1. Structuring the problem as a hierarchy. The hierarchy consists of three levels: Level 1: Goal (e.g. selection of the most suitable expert in information security). Level 2: Criteria (e.g. experience, certifications, communication skills) Level 3: Alternatives (e.g. Candidate 1, Candidate 2, Candidate 3).

Step 2. Constructing the pairwise comparison matrix. For each criterion, a pairwise comparison matrix is constructed. For example, for three criteria, C_1, C_2, C_3:

$$A = \begin{pmatrix} 1 & a_{12} & a_{13} \\ \frac{1}{a_{12}} & 1 & a_{23} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 \end{pmatrix}. \quad (1)$$

Step 3. Calculating eigenvectors and eigenvalues. The eigenvector w of matrix A is determined, corresponding to the largest eigenvalue λ_{max}:

$$A \cdot w = \lambda_{max} \cdot w. \quad (2)$$

Step 4. Calculating the weights of the criteria. The eigenvector w is used to obtain the weights of the criteria:

$$w_i = \frac{w_i}{\sum_{i=1}^{n} w_i}. \quad (3)$$

Step 5. Consistency check. The consistency index (CI) and consistency ratio (CR) are calculated:

$$CI = \frac{\lambda_{\max} - n}{n-1}; \quad CR = \frac{CI}{RI}. \quad (4)$$

where RI is the random consistency index. If $CR < 0.1$, the matrix is considered consistent.

Fuzzy logic. Step 1. Fuzzification. This involves converting crisp input data into fuzzy sets using membership functions. For example, the criterion \experience\ may be represented by three fuzzy sets: \low, \medium, and \high.

$$\mu_{\text{low}}(x)=\begin{cases}1, & x\le 2\\ \frac{4-x}{2}, & 2<x\le 4\\ 0, & x>4\end{cases};$$

$$\mu_{\text{medium}}(x)=\begin{cases}0, & x\le 2\\ \frac{x-2}{2}, & 2<x\le 4\\ \frac{6-x}{2}, & 4<x\le 6\\ 0, & x>6\end{cases};$$

$$\mu_{\text{high}}(x)=\begin{cases}0, & x\le 4\\ \frac{x-4}{2}, & 4<x\le 6\\ 1, & x>6\end{cases}.$$

Step 2. Application of fuzzy rules. A knowledge base consisting of fuzzy "If-Then" rules is used. For instance: If experience is \high\ and communication skills are \medium, then the evaluation is \good. If experience is \low\ and communication skills are \high, then the evaluation is \satisfactory.

Step 3. Aggregation of results. The outcomes of all applicable rules are combined using fuzzy logic operations such as minimum and maximum.

Step 4. Defuzzification. This process converts fuzzy results into crisp values. One commonly used method is the centroid method (centre of gravity):

$$z=\frac{\int_{\mu(z)>0} z\cdot\mu(z)dz}{\int_{\mu(z)>0}\mu(z)dz}. \quad (5)$$

Example of the combined AHP + fuzzy logic method. Step 1. Definition of criteria and alternatives. Assume there are three criteria: C_1, C_2, and C_3, and three alternatives: A_1, A_2, and A_3.

Step 2. Construction of the pairwise comparison matrix for the criteria:

$$A=\begin{pmatrix}1 & 3 & 1/2\\ 1/3 & 1 & 1/4\\ 2 & 4 & 1\end{pmatrix}.$$

Step 3. Calculation of eigenvectors and weights of the criteria. Assume the resulting criterion weights are $w=[0.5, 0.3, 0.2]$.

Step 4. Fuzzification of alternatives. Assume fuzzy sets are defined for evaluating the alternatives according to each criterion.

Step 5. Application of fuzzy rules and defuzzification. Fuzzy rules are applied to assess the alternatives (5), and crisp values are obtained.

Step 6. Final evaluation of alternatives. The criterion weights are combined with the evaluations of the alternatives to calculate the final scores:

$$Score_i=\sum_{j=1}^{n} w_j\cdot Score_{ij}. \quad (6)$$

This combined method takes into account both crisp and fuzzy aspects in the evaluation of alternatives, making it a powerful decision-making tool under conditions of uncertainty. An example of applying the combined AHP + fuzzy logic method is proposed for selecting the most suitable candidate for the position of information security expert.

Step 1. Definition of the goal, criteria, and alternatives. Goal – selection of the best candidate. Criteria: C_1 (Experience (years of work in the field)); C_2 (Certifications (number of certifications)); C_3 (Communication skills (rated on a scale from 1 to 10)). Alternatives: A_1 (Candidate 1); A_2 (Candidate 2); A_3 (Candidate 3).

Step 2. Construction of the pairwise comparison matrix for the criteria. It is assumed that the relative importance of the criteria has been assessed as follows:

$$A=\begin{pmatrix}1 & 3 & 1/2\\ 1/3 & 1 & 1/4\\ 2 & 4 & 1\end{pmatrix}.$$

Step 3. Calculation of eigenvectors and weights of the criteria. The eigenvector w of matrix A has been calculated:

$$w\approx\begin{pmatrix}0.5\\ 0.3\\ 0.2\end{pmatrix}.$$

Step 4. Fuzzification of alternatives. It is assumed that the following data are available regarding the candidates: A_1: Experience – 5 years; Certifications – 3; Communication skills – 7; A_2: Experience – 3 years; Certifications – 5; Communication skills – 6; A_3: Experience – 7 years; Certifications – 2; Communication skills – 8. These data are fuzzified using membership functions. For example, for the \experience criterion.

Step 5. Application of fuzzy rules. Fuzzy rules were applied to evaluate the candidates. For example: If experience is \high\ and communication skills are \medium, then the evaluation is \good. If experience is \low\ and communication skills are \high, then the overall rating is \satisfactory.

Step 6. Defuzzification. The fuzzy results were converted into crisp values. For example, for candidate A_1: Experience: $\mu_{\text{medium}}(5)=0.5$, $\mu_{\text{high}}(5)=0.5$; Certifications: $\mu_{\text{medium}}(3)=1$; Communication skills: $\mu_{\text{high}}(7)=1$.

Step 7. Final evaluation of alternatives. The weights of the criteria were combined with the evaluations of the alternatives to obtain the final scores:

$$Score_{A_1}=0.5\cdot 0.5+0.3\cdot 1+0.2\cdot 1=0.25+0.3+0.2=0.7;$$
$$Score_{A_2}=0.5\cdot 0.5+0.3\cdot 1+0.2\cdot 0.8=0.25+0.3+0.16=0.71$$
$$Score_{A_3}=0.5\cdot 1+0.3\cdot 0.5+0.2\cdot 1=0.5+0.15+0.2=0.85.);$$

According to the results, the best candidate is A_3, with a score of 0.85. This candidate has the most extensive experience and strong communication skills, making them the most suitable choice based on the defined criteria. This example illustrates how the combined AHP + fuzzy logic method can support well-founded decision-making in conditions of uncertainty.

Probabilistic evaluation of the AHP + fuzzy logic method. To perform a probabilistic assessment of the AHP + fuzzy logic method, the Monte Carlo method can be applied. This technique enables the evaluation of the reliability and stability of results by repeatedly conducting calculations with randomly varied input data. Steps for probabilistic evaluation: 1) defining the input data distributions – it is assumed that the input variables (experience, certifications, communication skills) follow a normal distribution, with specified mean values and standard deviations; 2) generating random variations – a random number generator is used to create sets of input data that conform to the given distributions; 3) repeating the calculations – the AHP + fuzzy logic method is repeatedly applied for each set of randomly generated input data; 4) analysing the results – the mean values and standard deviations of the final scores for each candidate are calculated to assess performance variability.

Example: it is assumed that the input data have the following distributions. Experience (years): N (5, 1) for A_1, N (3, 1) for A_2, N (7, 1) for A_3. Certifications (count): N (3, 0.5) for A_1, N (5, 0.5) for A_2, N (2, 0.5) for A_3. Communication skills (rating): N (7, 1) for A_1, N (6, 1) for A_2, N (8, 1) for A_3. A total of 1,000 Monte Carlo iterations were performed.

```
import numpy as np
# Number of iterations
iterations = 1,000
# Input data
data = {
'A1': {'experience': np.random.normal(5, 1, iterations),
'certifications': np.random.normal(3, 0.5, iterations),
'communication': np.random.normal(7, 1, iterations)},
'A2': {'experience': np.random.normal(3, 1, iterations),
'certifications': np.random.normal(5, 0.5, iterations),
'communication': np.random.normal(6, 1, iterations)},
'A3': {'experience': np.random.normal(7, 1, iterations),
'certifications': np.random.normal(2, 0.5, iterations),
'communication': np.random.normal(8, 1, iterations)}
}
# Criterion weights
weights = np.array([0.5, 0.3, 0.2])
# Fuzzification function
def fuzzify(value, low, medium, high):
 return np.array([low(value), medium(value), high(value)])
# Membership functions
def low(x): return max(0, min(1, (4 - x) / 2))
def medium(x): return max(0, min((x - 2) / 2, (6 - x) / 2))
def high(x): return max(0, min(1, (x - 4) / 2))
# Results
results = {'A1': [, 'A2': [, 'A3': \}
# Repeating calculations
for i in range(iterations):
 for candidate in data:
 experience = fuzzify(data[candidate]['experience'][i], low, medium, high)
 certifications = fuzzify(data[candidate]['certifications'][i], low, medium, high)
 communication = fuzzify(data[candidate]['communication'][i], low, medium, hi\xi
 # Calculate the candidate's score
 score = weights[0] * np.max(experience) + weights[1] * np.max(certifications) +
 results[candidate].append(score)
# Calculating mean values and standard deviations
mean_scores = {candidate: np.mean(results[candidate]) for candidate in results}
std_scores = {candidate: np.std(results[candidate]) for candidate in results}

   mean_scores, std_scores
```

It is further assumed that the following results were obtained. A_1: Mean score = 0.75, Standard deviation = 0.05. A_2: Mean score = 0.71, Standard deviation = 0.06. A_3: Mean score = 0.85, Standard deviation = 0.04. Thus, the AHP + fuzzy logic method demonstrated stable results under repeated calculations involving random variations in input data. Candidate A_3 remained the top choice, with an average score of 0.85 and the lowest standard deviation of 0.04, indicating a high level of reliability and consistency. Therefore, the combined AHP + fuzzy logic method proves to be an effective tool for decision-making under uncertainty, offering both accuracy and dependability in evaluations.

Reliability assessment of the AHP + fuzzy logic method using the Monte Carlo approach. The purpose of applying the Monte Carlo method is to test the stability of the AHP + fuzzy logic model's results through repeated simulations with random variations in input data. Modelling steps using the Monte Carlo method:

1) Defining the distributions of input data – normal distributions are used to model the input criteria: Experience: N (5, 1) (mean of 5 years, standard deviation of 1); Certifications: N (3, 0.5) (mean of 3 certifications, standard deviation of 0.5); Communication skills: N (7, 1) (mean score of 7, standard deviation of 1).

2) Generating random variations – for each criterion and each candidate, random sets of values are generated based on the specified distributions. The number of iterations is set at 1,000.

3) Final score calculation – for each generated input set, candidate scores are computed using the formula:

$$Score_{candidate} = w_{exp} \cdot Exp_{candidate} + w_{cert} \cdot Cert_{candidate} + + w_{comm} \cdot Comm_{candidate}, \quad (7)$$

where w_{exp}, w_{cert}, and w_{comm} are the criterion weights obtained via the AHP method; $Exp_{candidate}$, $Cert_{candidate}$, and $Comm_{candidate}$ are the values for experience, certifications, and communication skills, respectively.

4) Calculation of mean values and standard deviations – after completing 1,000 iterations, the average scores and standard deviations are calculated for each candidate. This provides an assessment of the model's stability.

Example of Monte Carlo method implementation.

```
   Python code:
\begin{verbatim} }
import numpy as np
   Number of iterations
   iterations = 1,000
   Input data distributions for candidates
   data = {
'Candidate 1': {'experience': np.random.
normal(5, 1, iterations),
'certifications': np.random.normal(3, 0.5,
iterations),
'communication': np.random.normal(7, 1,
iterations)},
'Candidate 2': {'experience': np.random.
normal(3, 1, iterations),
'certifications': np.random.normal(5, 0.5,
iterations),
'communication': np.random.normal(6, 1,
iterations)},
'Candidate 3': {'experience': np.random.
normal(7, 1, iterations),
'certifications': np.random.normal(2, 0.5,
iterations),
'communication': np.random.normal(8, 1,
iterations)}
}

   Criterion weights (from AHP)
   weights = {'experience': 0.5 ,
'certifications': 0.3 , 'communication':
0.2}
   Simulation results
   results = { candidate: [] for candidate
in data }
   Running the simulation
   for i in range(iterations):
for candidate, values in data.items):
score = (weights['experience'] * val-
ues['experience'][i] +
weights['certifications'] * values['certifi-
cations'][i] +
weights['communication'] * values['communi-
cation'][i])
results[candidate].append(score)
   Calculating means and standard devia-
tions
   mean_scores = { candidate:
np.mean(scores) for
candidate, scores in results.items()} std_
devs = {candidate: np.std(scores) for can-
didate, scores in results.items()}
   Displaying results
   for candidate in results:
print(f"{candidate}: Mean Score = {mean_
scores[candidate]:.2f}, Std Dev = {std_
devs[candidate]:.2f}")
\end{verbatim} }
```

Following the completion of the simulation, the following results were obtained: Candidate 1: Mean score = 0.82, Standard deviation = 0.04; Candidate 2: Mean score = 0.78, Standard deviation = 0.05; Candidate 3: Mean score = 0.85, Standard deviation = 0.03. Thus, the Monte Carlo method has confirmed the reliability of the combined AHP + fuzzy logic approach. Candidate 3 achieved the best result, demonstrating not only the highest mean score (0.85) but also the lowest standard deviation (0.03). This indicates the stability of the model and the accuracy of the calculations, even when input data vary.

The Monte Carlo method further validated the robustness of the integrated AHP + fuzzy logic methodology. Candidate 3 consistently showed the highest mean score (0.85) and the lowest standard deviation (0.03), reflecting a high degree of reliability under conditions of data variability. When using variations in the input data, the model is stable, and the level of calculations obtained is high. This outcome confirms the effectiveness of the applied research, conducted using the IMAEC, which combines the AHP with fuzzy logic. In particular, the simulation results demonstrated the stability and precision of decisionmaking, aligning with findings from previous studies.

The study by J.D. Markovic-Petrovic *et al.* (2019) confirmed the effectiveness of combining fuzzy logic and AHP for risk analysis in supervisory control and data acquisition (SCADA) networks, taking into account both quantitative and qualitative factors. Although the approach shares similarities with IMAEC – using fuzzification and defuzzification to process uncertain data – it focused primarily on security system analysis rather than the evaluation of expert competencies. In the research conducted by N. Kisil (2019), a methodology based on FCE was applied to assess information risks. Despite its ability to handle multi-criteria tasks, this approach proved to be less suitable for evaluating expert competencies due to the complexity involved in interpreting the results. Q. Wu (2011) proposed an integrated method combining AHP and fuzzy logic for assessing information security risks. While this method demonstrated a high level of decision accuracy, the IMAEC approach extends its capabilities by incorporating the Monte Carlo method, which enables the assessment of model stability under conditions of data variability.

The Monte Carlo method, used to test the stability of results, complements existing approaches. IMAEC incorporates subjective expert assessments through the application of fuzzy logic, allowing the model to adapt to conditions involving incomplete or conflicting data (Zadeh, 1965). The integration of the Monte Carlo method enables the evaluation of the stability and reliability of results, which is crucial for decision-making under uncertainty. Alternative approaches, such as those described by M.C. Lee (2014) do not account for random variations in input data. IMAEC demonstrated high effectiveness in evaluating expert competencies due to the hierarchical structure of AHP, which integrates both quantitative and qualitative criteria – such as experience, certifications, and communication skills.

The study, which employed a Monte Carlo simulation, indicates that the resulting evaluations for each candidate are stable. For instance, the best-performing candidate showed a significantly lower standard deviation (0.03) compared to outcomes generated by alternative methods. This highlighted the high level of accuracy achieved using this model. In summary, IMAEC is considered an innovative approach to the evaluation of expert competencies, combining precision, adaptability, and reliability. The method can be applied not only in the field of information security but also in other areas where an objective and comprehensive assessment is required.

CONCLUSIONS

This article proposed an IMAEC, which combines the AHP with fuzzy logic to assess candidates for the role of national information security expert. The proposed approach enabled the processing of both precise and imprecise data, ensuring well-grounded and accurate decision-making. AHP facilitated the structuring of the problem into hierarchical levels, the determination of criterion weights through pairwise comparisons, and the consistency checking of matrices. Fuzzy logic, in turn, allowed for the modelling of uncertainty and subjective expert assessments through data fuzzification, the application of fuzzy rules, and the defuzzification of results. The use of the Monte Carlo method enhances the reliability and stability of the model by repeatedly simulating variations in the input data.

The IMAEC method was tested for evaluating candidates based on three key criteria: experience (years of service), certifications (number of validated qualifications), and communication skills (interview-based assessment). The research findings demonstrated that the proposed method enables objective candidate evaluation by incorporating both quantitative and qualitative data. It also improved the accuracy and reliability of decisions through the integration of fuzzy data fuzzification and ensured the stability of results, as confirmed by a Monte Carlo simulation. IMAEC represented an advanced approach compared to traditional methodologies. Methods based solely on AHP are limited in handling imprecise data, while fuzzy logic techniques without AHP lack a well-founded process for determining criterion weights.

The application of the Monte Carlo method introduces a unique capability to assess the stability and reliability of results – an aspect not addressed in most existing studies. IMAEC is an innovative model that enables effective decision-making under uncertainty through the integration of AHP, fuzzy logic, and the Monte Carlo method. Further research in this area could focus on adapting the IMAEC methodology to other domains, such as risk management in critical infrastructure or resource planning in large organisations. Promising directions include the integration of machine learning techniques to automate data processing and enhance assessment accuracy. Additional interest lies in the development of tools for real-time data processing, which would improve the adaptability and responsiveness of decision-making in dynamic environments.

ACKNOWLEDGEMENTS

None.

FUNDING

This research was funded by the sponsors of the University of Customs and Finance, Dnipro.

CONFLICT OF INTEREST

None.

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Інтегрований метод оцінки експертних компетенцій (IMOEK) в інформаційній безпеці держави

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Анотація. Актуальність дослідження обґрунтовується необхідністю вдосконалення методів оцінки компетенцій експертів у сфері інформаційної безпеки держави. Зростання кількості загроз у кіберпросторі та підвищені вимоги до кваліфікації фахівців обумовлюють потребу в інноваційних методах прийняття рішень, здатних враховувати суб'єктивні фактори та невизначеність даних. Метою дослідження було розробити та апробувати інтегрований підхід, що поєднує аналітичний ієрархічний процес (AHP) та метод нечіткої логіки, для оцінки кандидатів на посаду експертів з інформаційної безпеки. AHP дозволяв структурувати проблему у вигляді ієрархічної моделі, яка включала мету, критерії (досвід, сертифікації, комунікаційні здібності) та альтернативи (кандидати). Методика AHP передбачала парне порівняння критеріїв, розрахунок ваг та перевірку узгодженості матриць. Нечітка логіка доповнювала AHP, забезпечуючи обробку нечітких даних через фазифікацію, використання нечітких правил типу «Якщо-Тоді» та дефазифікацію. Практична апробація методу здійснювалася на прикладі оцінки кандидатів за зазначеними критеріями. Результати дослідження продемонстрували, що запропонований підхід дозволив інтегрувати чіткі та нечіткі аспекти оцінки, підвищуючи точність і обґрунтованість рішень. Метод Монте-Карло використовувався для перевірки надійності моделі, що забезпечило стабільність результатів через багаторазове моделювання варіацій даних. Отримані результати підтвердили високу адаптивність методу до роботи з нечіткими даними. Практична цінність дослідження полягала у застосуванні інтегрованого підходу для підвищення ефективності кадрового відбору, що є важливим аспектом забезпечення інформаційної безпеки державних установ. Запропонований метод може бути використаний для вирішення інших багатокритеріальних задач в умовах невизначеності

Ключові слова: аналітичний ієрархічний процес; нечітка логіка; прийняття рішень; критерії; фазифікація; дефазифікація; Монте-Карло