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RANKING CHALLENGES, RISKS AND THREATS USING FUZZY INFERENCE SYSTEM

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Abstract. *This paper presents a Fuzzy Inference System (FIS) designed to comprehensively assess challenges, risks, and threats. In the realm of security and defense, defining these elements is inherently uncertain and complex. The paper addresses this challenge by integrating fuzzy logic into the model. As a pivotal instrument for decision-making, the model not only facilitates the precise identification of challenges, risks, and threats but also provides vital support for the strategic and doctrinal document development process. The methodology proves instrumental in reconciling divergent perspectives, aligning theoretical intricacies with practical applications. By effectively capturing the nuanced interplay between variables, the model offers a dynamic framework that enhances the accuracy and efficiency of security-related decision-making.*

Keywords: *fuzzy inference system (FIS), challenges, risks, threats.*

1. INTRODUCTION

The significance of studying Challenges, Risks, and Threats (CRT) stems from their pivotal role in formulating strategic and doctrinal documents within the realm of security and defense. Challenges, risks, and threats represent inescapable factors influencing the development of these documents, and their assessment stands as an

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initial phase in their formulation (Klinke & Renn, 1999). The evaluation of CRT defines the substance of core strategic and doctrinal documents in security and defense, such as the National Security Strategy of the Republic of Serbia, Defense Strategy of the Republic of Serbia, and the Doctrine of the Army of Serbia. Furthermore, it also extends to planning documents including the Long-term Plan for the Development of the Defense System of the Republic of Serbia, Strategic Review of Defense, and the Defense Plan for the Republic of Serbia (Tatomir, 2011). These documents adhere to the hierarchical structure characteristic of the Republic of Serbia. Despite variations in understanding document hierarchy and content among domestic and foreign authors in both practice and theory, the assessment of challenges, risks, and threats remains an indispensable component of any approach.

Building upon the National Security Strategy, which constitutes a framework of complementary norms, the national security system is established. This framework serves as the foundation for the integrated operation of security forces (Kovač & Stojković, 2009). Meanwhile, the Defense Strategy, and other relevant laws, forms the defense system, encompassing force structuring, funding, modernization, and more. Simultaneously, the military doctrine shapes the organization of military activities (Kovač & Stojković, 2009).

This underscores the paramount importance of precisely defining CRT security. An erroneous prediction could render an appropriate response ineffective when any of the CRTs pose a threat to reference security entities. According to Simić (2002), the security of the reference object is contingent on the interplay between threats and the potential to counteract those threats. Thus, developing a suitable model, which could subsequently be endorsed, holds significant significance in imparting a more objective definition of all three instances of security threats or substantially reducing subjectivity. This is especially crucial given that state leadership substantially shapes the formulation of key declarations in strategic documents (Kovač & Stojković, 2009). It is well recognized that, "First and foremost, elites safeguard the values they hold dear or those of the group to which they belong, in an effort to portray their specific values as national" (Dimitrijević, 1973). Supporting this perspective, Brauch (2005) highlights that the perception of CRTs is intertwined with the worldviews of analysts and political decision-makers.

The integration of fuzzy logic into decision-making models has emerged as a significant advancement in addressing complexity and uncertainty in various domains (Pamučar et al., 2012; Božanić et al., 2021; Narang et al., 2023; Sahoo & Goswami, 2023; Naseem et al., 2023; Tripathy, 2023), including security and defense (Bayramov et al., 2023; Güneri & Deveci, 2023; Kamalov et al., 2023). Fuzzy logic, a computational approach that accounts for vagueness and imprecision, has found application in diverse fields due to its ability to handle uncertain and incomplete information (Đuričić, 2023; Tešić et al., 2023). In the context of security and defense, where challenges, risks, and threats are multifaceted and often lack well-defined boundaries (Cristea, 2020), the incorporation of fuzzy logic offers a promising avenue to enhance decision-making processes (Štilić et al., 2023).

The use of fuzzy logic in security-related assessments builds upon a foundation of research within the broader field of decision support systems and risk analysis. Traditional decision-making models often rely on crisp, binary categorizations (Wahid et al., 2023; Kollati & Debnath, 2021), which can lead to oversimplification and inadequate representation of complex realities. Fuzzy logic, on the other hand, enables the modeling of gradations and degrees of membership, allowing for a more nuanced representation of uncertainties inherent in security contexts (Božanić & Pamučar, 2010; Si & Ganguly, 2021; Obradović & Pamučar, 2020).

Current research has explored the application of fuzzy logic in addressing various aspects of security analysis. For instance, research by Kumar et al. (2020) demonstrated the effectiveness of fuzzy logic in evaluating cyber threats by considering multiple factors with varying degrees of importance. Similarly, researchers (Çolak et al., 2022; Tabesh et al., 2021) extended the application of fuzzy logic to assess the likelihood and impact of terrorist threats, demonstrating how linguistic variables can capture expert knowledge and improve decision-making accuracy.

The integration of fuzzy logic into the model presented in the current paper not only contributes to the assessment of challenges, risks, and threats but also holds promise in supporting the development of strategic and doctrinal documents. This aligns with the broader trend observed in defense literature, where decision-support tools play a critical role in shaping policies and strategies (Karakosta et al., 2021; Marin et al., 2021). Different researches (Sánchez-Lozano et al., 2022; Santos et al., 2019) exemplifies how decision support systems aid in formulating defense policies that account for diverse and uncertain variables.

Furthermore, the integration of fuzzy logic addresses the challenge of reconciling divergent perspectives often encountered in security and defense contexts. As highlighted by Wang et al. (2023) the incorporation of linguistic variables through fuzzy logic enables decision-makers to capture and integrate subjective judgments, leading to more inclusive and comprehensive analyses.

The dynamic framework proposed by the model aligns with the evolving nature of security considerations. In a rapidly changing global landscape, the ability to adapt and update assessments in real-time is crucial. This sentiment is echoed in the work (Efthymiopoulos, 2019; Settembre-Blundo et al., 2021) that emphasized the need for flexible decision-making tools that can accommodate new information and changing circumstances.

The utilization of fuzzy logic in the model presented in this paper represents a significant contribution to the field of security and defense decision-making. Building upon established literature in decision support systems, risk analysis, and defense policy formulation, the model addresses the intricate challenges of uncertainty and complexity. By embracing fuzzy logic's capacity to capture nuanced relationships between variables, the model offers a valuable framework for enhancing the accuracy, efficiency, and adaptability of security-related decision-making processes. As security concerns continue to evolve (Snow, 2019), this and similar models stand as beacons of strategic clarity, equipping decision-makers with the tools to navigate the multifaceted terrain of security and defense effectively.

The introduction is followed by a section in which the concepts of challenges, risks, and threats are defined. Then, a general description of the fuzzy inference system (FIS) is briefly provided so that, in the fourth unit, the procedure for designing the FIS can be presented. Finally, the created model was successfully tested.

2. CHALLENGES, RISKS AND THREATS

Like many concepts in social sciences, CRTs lack a consensus in their definitions, despite numerous attempts. The delineation of these concepts hinges on the period of examination, the actors involved, the intended purposes, the scientific or professional methodologies employed, and more. Successfully defining and categorizing contemporary challenges, risks, and threats within security studies necessitates the establishment of reference objects – what is being safeguarded. In this context, two vital reference objects emerge: the state (including sovereignty) on one side and the individual (society) along with its identity on the other (Orlić, 2004). Both these reference objects are pivotal for problem analysis, as the state, upon losing its sovereignty, forfeits its status as a state, while the survival of society hinges on the preservation of its identity (Roe, 2010). Other reference objects hold less significance in addressing this issue, or they can be perceived through the lens of the previously outlined ones.

The concept of security is frequently intertwined with danger in the viewpoints of scholars engaged in this field. This association permeates into the conceptual delineation of challenges, risks, and threats. For instance, Dimitrijević (1973) defines danger as heightened risk, which corresponds to the potential for harm (pertaining to value). He also highlights the cognitive aspect, which relates to the probability of the harm occurring.

Orlić (2004) considers challenges as conceivable forms of jeopardizing state stability, sovereignty, and the identity of individuals and society. Risks, in his framework, encompass "more immediate and quantifiable forms of endangering the sovereignty and identity of both state and society," whereas threats denote "direct forms of endangerment to the state and society." While challenges bear a neutral connotation for the state and society, risks and threats carry negative implications and can emanate from one another. Depending on the response to a challenge, it can be assessed with a positive sign when the reaction leads to resolution or with a negative sign by escalating into a risk or threat (Orlić, 2004). Within the realm of risk, there lies the opportunity to evade detrimental consequences for the security of the reference object, while threats entail explicit, foreseeable, and definite forms of endangerment (Orlić, 2004). Tatomir (2011) presents a similar gradation of CRTs.

In the domain of Risk Management, challenges, risks, and threats are perceived differently. Here, "risk" serves as a central concept, with varying definitions depending on the author's perspective and ultimate intent. More insights can be found in (Keković et al., 2011; Božanić et al., 2015; Karović, 2015).

Upon scrutinizing existing literature, two approaches emerge. The first, aligned with security, links CRTs to the extent of danger. In this view, challenges are associated with a minimal degree of danger to the reference object, wherein challenges can be redirected toward positive reactions. Risks correspond to a higher degree of danger per reference object, with an emphasis on the uncertain nature of the impending danger, though it exists to a certain extent. On the other hand, threats are almost certain and demand immediate response. This can be visually represented as depicted in Figure 1.

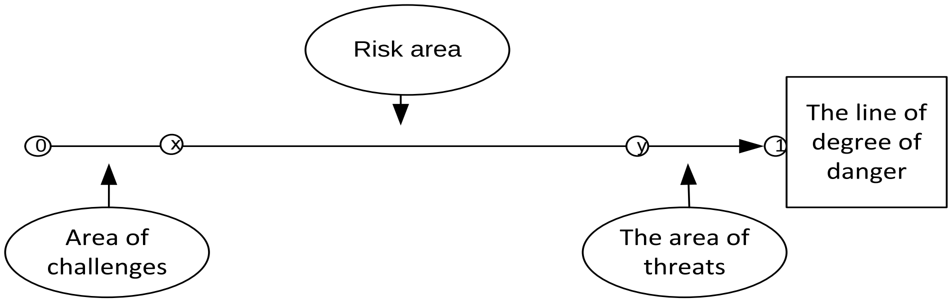

Figure 1. Graphical presentation of challenges, risks and threats in relation to the degree of danger

Another approach, rooted in risk management, places "risk" as the central concept, whereas threats are often seen as elements that can heighten the degree of risk. Accordingly, the threat is positioned as a single factor influencing risk assessment, though not the sole factor. Similar to the prior representation, risk can be defined graphically, as shown in Figure 2. In this context, the pivotal aspect is determining the acceptable level of risk.

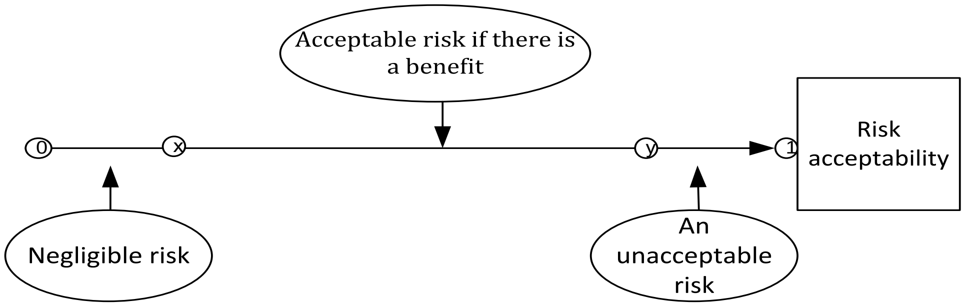

Figure 2. Graphic representation of risk in relation to the degree of acceptability (Božanić et al., 2015)

In a specific context, certain parallels can be discerned between the security-based and risk management-based approaches, prompting the question of whether it is a matter of terminology or a genuine divergence of concepts. To construct the model, drawing from security terminology, insights from both realms will be integrated.

3. FUZZY INFERENCE SYSTEM

FIS serve as models founded upon fuzzy logic and fuzzy sets. Further exploration in these domains can be found in works by Zadeh (1965), Teodorović & Kikuchi (1994), Ullman (1983) and Pamučar et al. (2011a). The overarching model's visualization, which is best depicted in the work, is expounded upon in Figure 3.

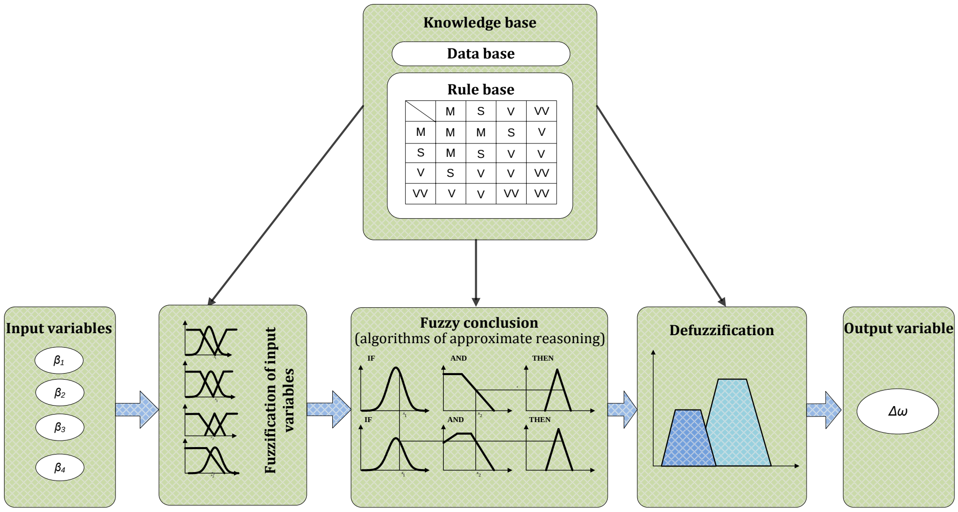

Figure 3. General appearance of the FIS (Pamučar et al., 2011a)

For an in-depth understanding of the functioning of the FIS, comprehensive descriptions can be found in the papers of Pamučar et al. (2011a) and Pamučar et al. (2011b). Acknowledging that models can never entirely mirror reality (Čupić & Suknović, 2010; Granados et al., 2023; Ulutaş et al, 2022), this model serves as an aid to decision-makers. Consequently, in certain circumstances, regardless of decision-making preferences, decision-makers may arrive at conclusions that don't align with the data derived from the model's output (Zhou et al., 2022; Jangid & Kumar, 2022; Bošković et al., 2023; Mzili et al., 2023).

4. THE DESIGN OF FIS

This section concisely details the input parameters/criteria and outlines the process of crafting and fine-tuning the FIS. This section constitutes the focal point of the paper.

4.1. Defining input parameters

Through analysis of the literature (Stanarević & Ejdus, 2009; Buzan, 1983; Dimitrijević, 1973; Johns, 2011; Keković et al, 2011; McGill & Ayyub, 2007; Tatomir, 2011; Ullman, 1983), the separation of four key elements is undertaken - pulse parameters influencing CRT definition:

C1 - Possible Consequences or Damages. This criterion encompasses the potential consequences of a given peril, including human, material, and systemic implications.

C2 - Probability of Occurrence. This criterion gauges the extent to which the damage/consequences may manifest.

C3 - State of the System. This criterion evaluates the system's state concerning potential hazards. It includes an assessment of the system's resistance in the face of danger and the system's vulnerability.

C4 - Subjective Aspect or Perception of Occurrence. In contrast to the preceding three criteria rooted in materialistic logic, this specific criterion delves into the socioconstructivist approach to security. It sheds light on how the observed event is perceived within the public sphere. The previous three criteria function within a framework of materialistic logic, originating from a rationalistic approach to security. Nevertheless, empirical evidence demonstrates that certain incidents are labeled as threats regardless of their objective state, aligning with the socioconstructivist approach to security. The subjective perception of CRT is not a novel concept; rather, it stands as an essential element of this issue. Buzan et al. (1998), Dimitrijevic (1973), and Kekovic et al. (2011) contribute to this context. As a result, this criterion elucidates how the observed event resonates within the public domain.

A set of input criteria C_i (i = 1,2,3,4) consists of two subgroups:

C^+ - A subset of favorable-type criteria where a higher criterion value is preferable (criterion C3), and

C^- - A subset of cost-type criteria where a lower value is preferable (criteria C1, C2, and C4)

All criteria possess linguistic attributes, allowing various linguistic scales. This paper employs a three-step linguistic scale to ensure sensitivity.

4.2. Creating and configuring the FIS

Fuzzy logic-based models usually require multiple iterations. Initially, a set of rules and corresponding membership functions are defined. Following results analysis, adjustments to individual rules and/or membership functions are made, if necessary. The modified rules and/or functions are then retested.

Selecting membership functions and their range within the confidence interval is a crucial stage in model design. In this fuzzy system, Gaussian curves are adopted for their ease of manipulation when setting outputs. Input variables are represented by three membership functions, while the output employs five. The confidence interval ranges numerically from 0 to 1 for each input and output variable. Figures 4 and 5 illustrate the membership functions for input and output linguistic variables, before setting the FIS.

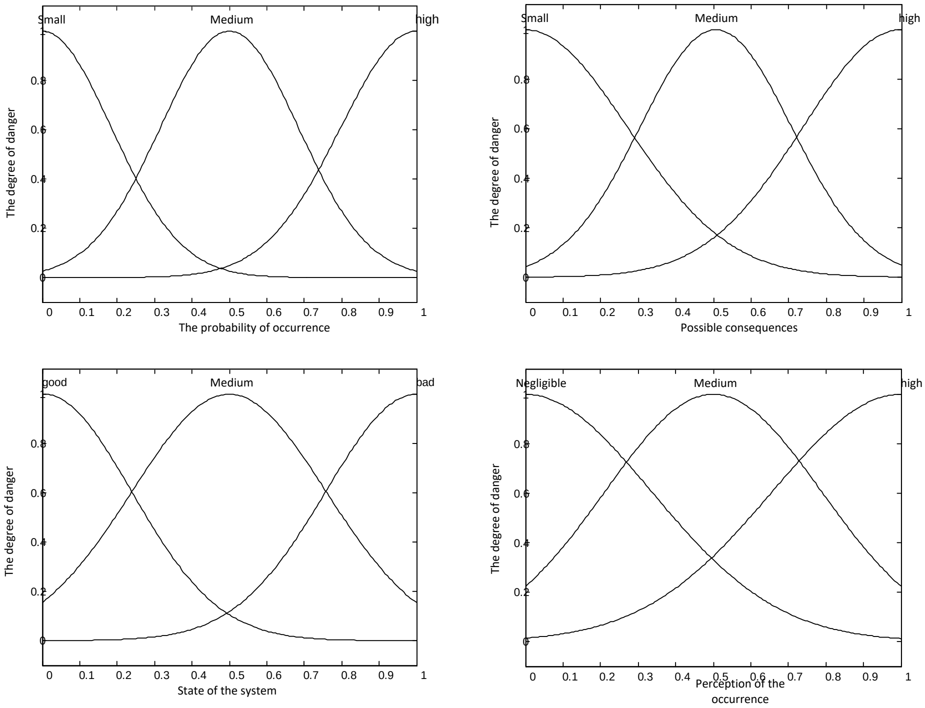

Figure 4. The functions of belonging to the input linguistic variables

The membership functions for the output linguistic variable are depicted in Figure 5.

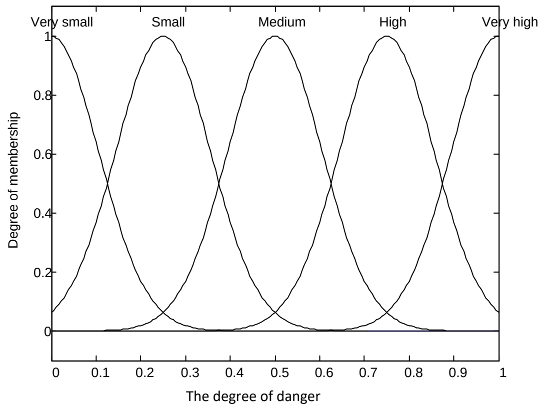

Figure 5. Functions belonging to the output variable

With four input variables (n = 4) possessing three linguistic values (M = 3), a rule base is formed with a total of Mn = 3^4 = 81 rules. The PROD-SUM method of direct conclusion was employed for the model, yielding an acceptable representation, as shown in Figure 6.

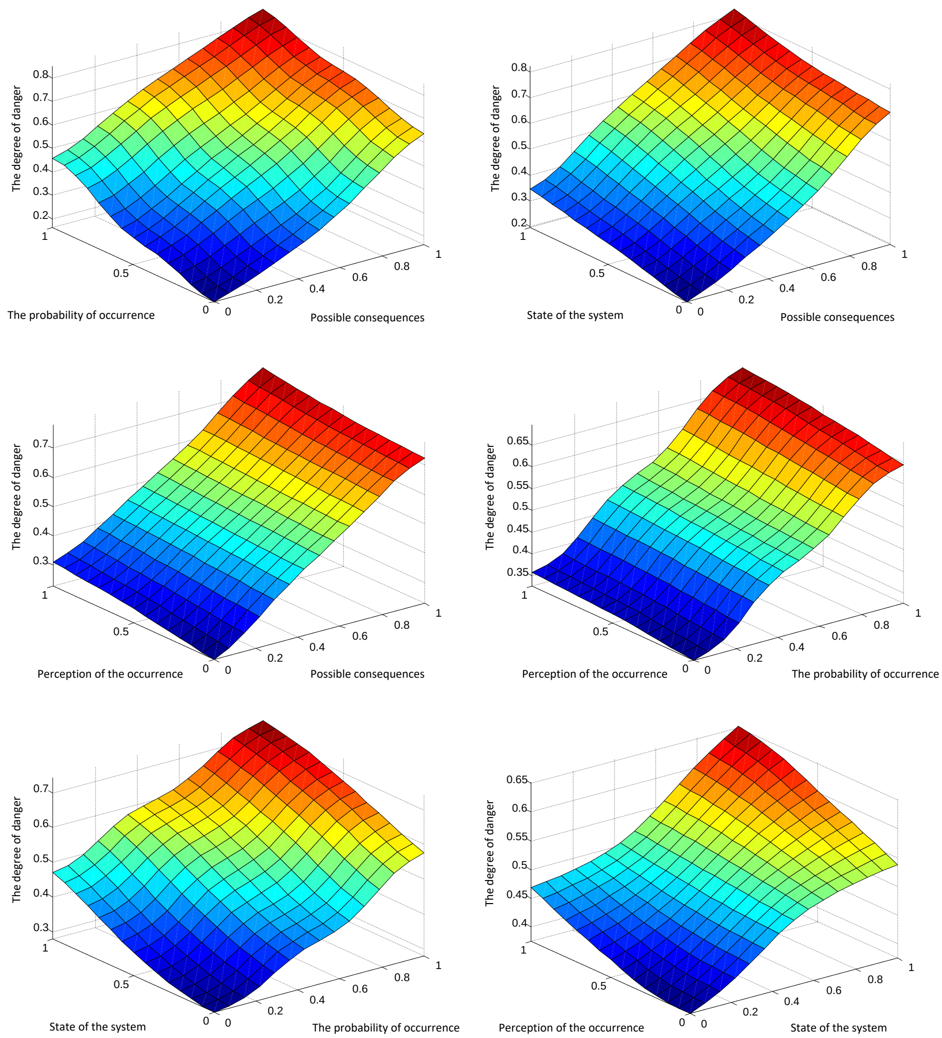

Figure 6. A graphic representation of a set of possible solutions

5. TESTING OF FIS

Testing and subsequent practical application constitute the logical phases within the model's lifecycle. During testing, necessary corrections, adjustments, or enhancements are implemented. To test this model, five specific occurrences were selected (Table 1). These events were evaluated by consensus among three experts, with the primary goal of demonstrating how the model operates. To obtain reliable estimates for each criterion, it is necessary to collect information from the field and involve a greater number of experts. Their participation is crucial in formulating strategic and doctrinal documents.

Table 1. Description of the occurrence for testing the FIS

Name of occurrence	C1	C2	C3	C4
The armed aggression	High	Small	Good	Medium
The proliferation of weapons of mass destruction	Medium	Medium	Medium	Negligible
Energy problems	Medium	High	Bad	High
Migrant crisis	Medium	High	Medium	Medium
Problems of economic development	High	Medium	Medium	High

Upon applying the model, the outcomes are presented in Table 2.

Table 2. Preference values obtained by applying the FIS

Occurrence	Preference for decision
The armed aggression	0,54
The proliferation of weapons of mass destruction	0,46
Energy problems	0,85
Migrant crisis	0,71
Problems of economic development	0,76

Utilizing the favored decision-making method, events are ordered by their level of danger, facilitating the delineation of challenges, risks, and threats. This categorization unfolds across a spectrum with specific values: up to 0.30 denotes challenges, 0.31 to 0.80 signifies risks, and surpassing 0.81 indicates threats. Thus, in the given case, energy problems represent a threat to the security of referent objects of the Republic of Serbia, while the other three events represent risks, with problems of economic development representing a risk with a fairly high degree of danger (potential threat). Additionally, the migrant crisis has a high priority and can potentially escalate into a threat. It is possible to define the scale differently depending on the perception of the analysts conducting it, the current state of events, etc.

6. CONCLUSION

Model testing has demonstrated the applicability of fuzzy logic to the presented problem. Consequently, effective ranking of the proposed options has been accomplished, streamlining the final decision-making process concerning CRT security definitions. This holds particular significance considering that the discussed problem constitutes just one facet of the array of decisions faced by decision-makers. Integrating this model streamlines decision-making time and alleviates the decision-maker's burden. Additionally, it mitigates the potential inexperience of decision-makers, as the model guides them toward a specific thought process.

By devising a fuzzy model, the strategy for CRT definitions transforms into an automated control strategy. This model, founded on text analysis and the experience of a smaller group of experts (three experts), offers an initial glimpse into the potential applications of fuzzy logic within this realm. The model's success will directly hinge on the engagement of skilled individuals in research and system development, as well as the analysts' ability to formulate decision strategies through extensive communication with them. Furthermore, enhancing the developed fuzzy system through integration into an adaptive neural network with learning capabilities holds promise.

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