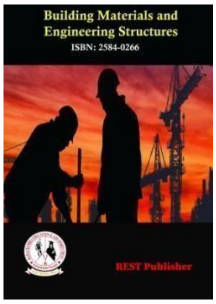
Building Materials and Engineering Structures
Vol: 1(3), September 2023
REST Publisher; ISSN: 2584-0266 (Online)
Website: https://restpublisher.com/journals/bmes/
DOI: https://doi.org/10.46632/bmes/1/3/5



Risk Assessment of Critical Infrastructures using COPRAS Method

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Abstract: *Because of their significance to security of the nation, societal security and way of living safety critical infrastructures play an important role in nations. Given the significance of infrastructure, it is essential to analyse possible hazards in order to prevent them from becoming events. The primary aim of this thesis is to demonstrate an established framework with the goal of surpassing the drawbacks of the traditional method to creating, implementing, and controlling more secure, safe, and flexible critical infrastructures. The suggested framework expands on the traditional "RAMCAP (Risk Analysis and Management for Critical Asset Protection)" framework by adding new risk-related parameters. Because of the problem's complexity and inherent uncertainty, COPRAS is used in this research as a decision-making method based on multiple criteria to determine the weights for each criterion and the importance of alternatives in relation to the criteria. Case studies are used to demonstrate the model's capability as well as efficacy in risk-ranking vital infrastructures. When compared to conventional RAMCAP, the suggested model performs significantly better.*

Keywords: *risk assessment*, *RAMCAP methodology, COPRAS methods*

1. INTRODUCTION

Countries all over the world have lately experienced a number of incidents in the critical infrastructure sector caused by a variety of factors. They result in numerous fatalities and extensive harm to people, machinery, and the environment. Many cases have shown that risks to safety, security, Health and the environment cannot be avoided completely. As a result, different methods for analysing and ranking existing risks were developed. The Department of Homeland Security's RAMCAP technique is one of the most widely used in this field. "The RAMCAP methodology is a function of three components: Threat (T), Vulnerability (V) and Consequence (C)". Regardless of the varying weights of the criteria for evaluation, it appears that essential infrastructures have a pressing need to develop a risk assessment method for managing successful components. "COPRAS (Complex Proportion Estimation) is a popular Multi-Criteria Decision Making (MCDM) technique that determines the best solution from a set of potential solutions by finding the ratio and percentage that constitutes the best solution. Various researchers use this technique to solve decision-making issues. Kaklaskas et al. used COPRAS to pick low-power windows in the retrofit of public buildings. Panaideen et al. used COPRAS to evaluate the life cycle of buildings. Chatterjee et al. created two COPRAs and assessed mixed data techniques for product selection. This paper provides two examples that show how these two MCDM methods can be used to handle real-time choice of materials problems. Zavatskas et al. used COPRAS to evaluate the risk of construction projects. Majumdar et al used COPRAS to evaluate teacher performance, while Karpassi et al (2008) used it to calculate energy savings. Ginevicius et al. (2010) used COPRAS to simulate the evolution of a firm's competing strategy in an oligopoly market. Podvezko et al (2010) used the COPRAS technique to evaluate the complexity of construction contracts". The SAW and COPRAS techniques were contrasted by Podvezko (2011). The RAMCAP methodology establishes a methodical approach for finding and assessing the importance of potentially dangerous infrastructure events. The RAMCAP process includes seven steps: "(1) asset characterization and screening, (2) threat characterization, (3) impact analysis, (4) vulnerability analysis, (5) asset attractiveness and threat assessment, (6) risk assessment, and (7) Risk management is all part of the process". 'The benefits of traditional RAMCAP include, but aren't restricted to, (i) more efficient capital and administration of human resources, (ii) the ability to pinpoint assets with the greatest requirement and value of enhancement, and (iii) rational resource allocation to maximize security and resilience growth within a budget that is restricted. The conventional RAMCAP method defines risk (R) as the intersection of attack consequences (C), attack threats (T), and attack vulnerabilities (V)'. The danger is specifically represented by an Equation.

2. THE SUGGESTED FRAMEWORK

The proposed framework for risk classification in essential infrastructure is divided into three stages: 1. Determine current risks. 2. Choose your evaluation parameters. 3. Use the COPRAS procedure to assess recognized risks.
Determine current risks: During the risk assessment process, hazards and dangers that could disrupt vital services and goods should be identified. One of the easiest ways to identify and analyze risks in infrastructure is to ask the right questions, such as what assets are most critical and which the majority vulnerable to danger are.
Criteria Selection: The first stage in assessing the risk of critical infrastructure is to choose criteria. The RAMCAP method's parameters were determined as component of the evaluation criteria. Because these criteria are inadequate to cover all risks, new criteria have been developed for more accurate, precise, and robust risk analysis. Table 1 summarizes these factors. Table 1 shows that the first three factors (C1, C2, and C3) are price category criteria. (lowest, best). The remaining factors are of the benefit variety. (more, better). "Threat (C1): A threat is defined as an event with an undesirable impact, Vulnerability (C2): Any weakness of an asset that can be caused by one or more threats to become an event or disaster, Consequence (C3): Consequence is defined as an event or incident, Detection (C4): Ability to identify and eliminate vulnerability Response to event (C5): The ability to respond appropriately in order to reduce or limit the effect of an event. Growth in casualty, damage and loss."
Case Study: To illustrate the model's potential applications, The proposed model is used to calculate the risk associated with vital infrastructure. API and NPRA have provided an illustration of rail transportation. (2004). A hypothetical hydrocarbon tank truck transportation system is used as an example, and it contains route-specific variables such as tank truck, flammable liquid presence and road style, population hubs and environmental receptors, and any pauses.
Risks Identification: In our instance, eight critical assets have been chosen as risky assets for the model to analyse. "These assets include 25 petroleum products (RPP), a rural area for switch yard - 25 miles from shipper base (RST), a rural main road - 200 miles (MST-200), switch yard (SY), river crossing (RC), A major part of an urban route - 300 miles (MST-300), in urban area (SUA), and tunnel in urban area (TUA)".

3. EVALUATING THE EXISTING RISKS USING COPRAS PROCEDURE

To assess the risks that were identified, 8 decision-makers with at least 5 years of experience were requested to rate the weights of criteria and alternatives for each criterion using the linguistic variables displayed in Tables 1 and 2. COPRAS were first proposed by Zavatskas and Kaklauskas (1996). A solution is determined using the COPRAS technique, which has a higher resolution rate. Describe the values and weights of alternative techniques and criteria in sufficient detail. The significance of the versions examined in the criterion setting this approach implies direct and proportional dependence and utility. Weights of scales and estimates of Soft's alternatives are used as numerical statistics in traditional cobras. However, under many circumstances, real-world decision-making issues arise. Smooth input is insufficient for handling. On the other hand, accurate knowledge is difficult to acquire. These factors also contribute to the accuracy of the findings."Alternative techniques and criteria values and compute the weights correctly The significance of versions examined in descriptive criteria setting this approach is direct and proportional bias and examines usability. The significance, order of priority, and extent of use of alternatives are determined in five steps: D is the weighted normal choice matrix. 2. Normalized weighted description of the option Symbol values are calculated. 3. Substitutes' benefits S+j and disadvantages S -j Describe and calculate the Qj values of the options under consideration. The extent to which substitute aj is used 5. Choosing the most important option."To pre-qualify bidders' five window replacement variants Based on the findings of the multi-criteria evaluation, the first option is superior, and the third version is essentially the second best. The usage percentage is 100%. The contractor's final selection is the next stage. Pre-qualification criteria were met after taking into account candidate bids. Following the completion of the technical evaluation, the final exam of the final short-listed contractors will be held in order to grant the contract. The technical score will be used to connect price proposals. Table 1 displays the evaluation factors. This subsection compares the model to conventional RAMCAP to show the capability and suitability of the risk assessment model proposed in this paper. To accomplish this, we use the standard RAMCAP for the previous case to finish the risk analysis. RAMCAP claims that risk is only a product of three factors: danger, vulnerability, and consequence magnitude. As shown in Table 8, an evaluation measure with five judgements was used, with 1 representing the lowest judgement level and 5 representing the highest. Table 8 summarises the evaluator team's results for assets. For comparison, COPRAS data is shown in the last column of Table 8.

4. RESULTS AND DISCUSSION

TABLE 1. Evaluation parameters Criteria for segmental attractiveness

C1	Consequence
C2	Detectability
C3	Reaction against event
C4	Threat
C5	Vulnerability

Table 1 gives Evaluation parameters for segmental attractiveness in the context of risk analysis typically include Consequence (C1), Detectability (C2), Reaction against event (C3), Threat (C4), and Vulnerability (C5). Consequence refers to the potential impact or severity of an event occurring within a segment. Detectability measures how easily an event can be identified within the segment. Reaction against event assesses the segment's ability to respond effectively to an event. Threat represents the likelihood of an event occurring within the segment. Vulnerability reflects the susceptibility of the segment to negative consequences from an event. These parameters help in evaluating the overall attractiveness of a segment from a risk perspective, aiding in the development of strategies to mitigate potential risks.

TABLE 2. Given a data set

	C1	C2	C3	C4	C5
RPP	50.926	46.875	183.333	78.947	91.837
RST	13.889	234.38	127.222	53.932	137.755
MST-200	51.926	351.56	61.111	53.642	91.837
SY	27.778	289.06	62.111	78.947	15.306
RC	28.778	575.52	61.411	53.632	139.755
MST-300	13.889	289.06	124.222	96.491	91.837
SUA	50.926	54.688	183.333	8.772	45.918
TUA	14.889	703.13	123.222	78.947	138.755

The data collection for risk analysis is shown in Table 2. In the above table, the C1, C2, C3, C4, and C5 of the return of "RPP, RST, MST-200, SY, RC, TUA, SUA, MST-300' are displayed. The other numbers are calculated using the above table.

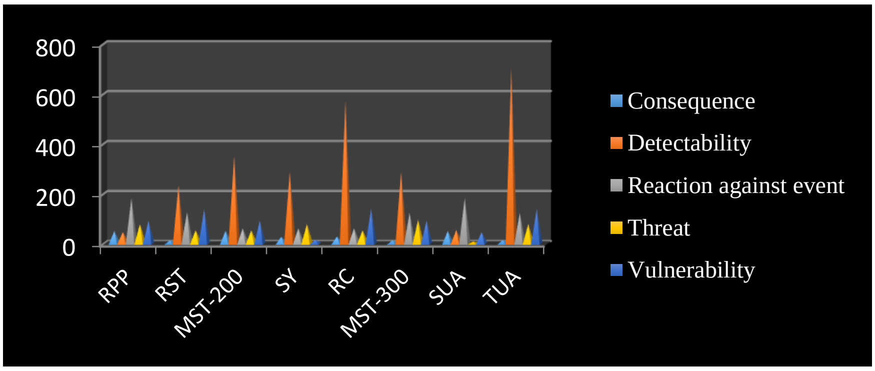

FIGURE 1. Data set for risk analysis

Figure 1 depicts the data set for risk analysis COPRAS, where the C1, C2, C3, C4, and C5 of return of "RPP, RST, MST-200, SY, RC, TUA, SUA, and MST-300' are displayed in the above tabulation.

TABLE 3. Normalized data

	C1	C2	C3	C4	C5
RPP	0.2013	0.0508	0.4226	0.2974	0.2727
RST	0.0961	0.2542	0.2933	0.2032	0.4091
MST-200	0.3593	0.3814	0.1409	0.2021	0.2727
SY	0.1922	0.3136	0.1432	0.2974	0.0455
RC	0.1991	0.6243	0.1416	0.2020	0.4150
MST-300	0.0961	0.3136	0.2864	0.3635	0.2727
SUA	0.3524	0.0593	0.4226	0.0330	0.1364
TUA	0.1030	0.7627	0.2841	0.2974	0.4121

Table 4: Given the normalised data calculated from the data set, "each value is determined by dividing the same value on the data set by the sum of the column of the above tabulation".

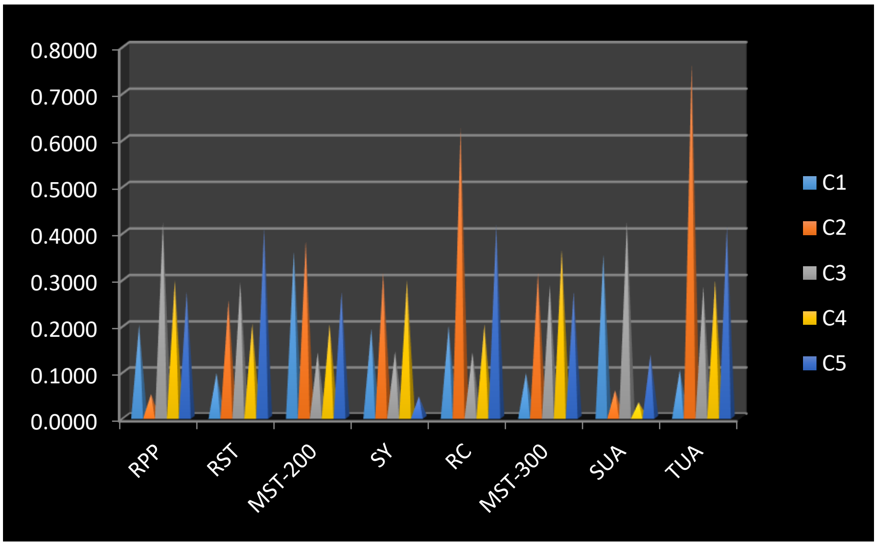

Figure 2. gives the normalized data

Figure 2 depicts the normalised data derived from the data set; each value is calculated by dividing the same value on the data set by the sum of the columns in the above tabulation.

TABLE 4. Gives weight matrix

	C1	C2	C3	C4	C5
RPP	0.20	0.20	0.20	0.20	0.20
RST	0.20	0.20	0.20	0.20	0.20
MST-200	0.20	0.20	0.20	0.20	0.20
SY	0.20	0.20	0.20	0.20	0.20
RC	0.20	0.20	0.20	0.20	0.20
MST-300	0.20	0.20	0.20	0.20	0.20
SUA	0.20	0.20	0.20	0.20	0.20
TUA	0.20	0.20	0.20	0.20	0.20

Table 4 displays the weight of the data set; the weight is the same for all values in the data set in table 1. To get the next value, multiply the weight by the prior table.

TABLE 5. Weighted normalization decision matrix

	C1	C2	C3	C4	C5
RPP	0.04	0.01	0.08	0.06	0.05
RST	0.02	0.05	0.06	0.04	0.08
MST-200	0.07	0.08	0.03	0.04	0.05
SY	0.04	0.06	0.03	0.06	0.01
RC	0.04	0.12	0.03	0.04	0.08
MST-300	0.02	0.06	0.06	0.07	0.05
SUA	0.07	0.01	0.08	0.01	0.03
TUA	0.02	0.15	0.06	0.06	0.08

The weighted normalisation decision matrix is shown in Table 5. 'It is determined by multiplying the weight and performance value in Tables 3 and 4'.

TABLE 6. Value of Bi, Ci, Min(Ci)/Ci, and Qi

	Bi	Ci	Min(Ci)/Ci	Qi
RPP	0.050	0.199	0.4896	0.166
RST	0.070	0.181	0.5367	0.197
MST-200	0.148	0.123	0.7894	0.335
SY	0.101	0.097	1.0000	0.338
RC	0.165	0.152	0.6407	0.316
MST-300	0.082	0.185	0.5268	0.207
SUA	0.082	0.118	0.8209	0.277
TUA	0.173	0.199	0.4892	0.289

The values of Bi, Ci, and Qi are shown in Table 6. The Bi is the total of the Specific strength, Specific Modulus, and Corrosion resistance. The Ci is determined by adding the cost categories together. Qi is derived from Bi and Ci.

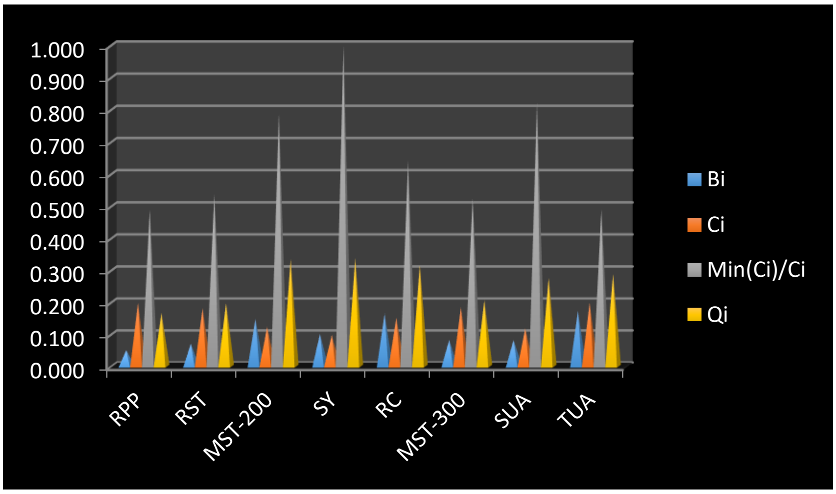

FIGURE 3. Bi, Ci, Min(Ci)/Ci, and Qi values

The values of Bi, Ci, and Qi are shown in Figure 3. The Bi is the total of the Specific strength, Specific Modulus, and Corrosion resistance. The Ci is determined by adding the cost categories together. Qi is derived from Bi and Ci.

TABLE 7. Ui values

	Ui
RPP	49.2251
RST	58.3414
MST-200	99.1471
SY	100.0000
RC	93.6223
MST-300	61.1577
SUA	81.8858
TUA	85.5138

Table 6 shows how Ui is determined using Qi. The RPP Ui is 49.2251, the RST Ui is 58.3414, the MST-200 Ui is 99.1471, the SY Ui is 100.0000, the RC Ui is 93.6223, the MST-300 Ui is 61.1577, the SUA Ui is 81.8858, and the TUA Ui is 85.5138.

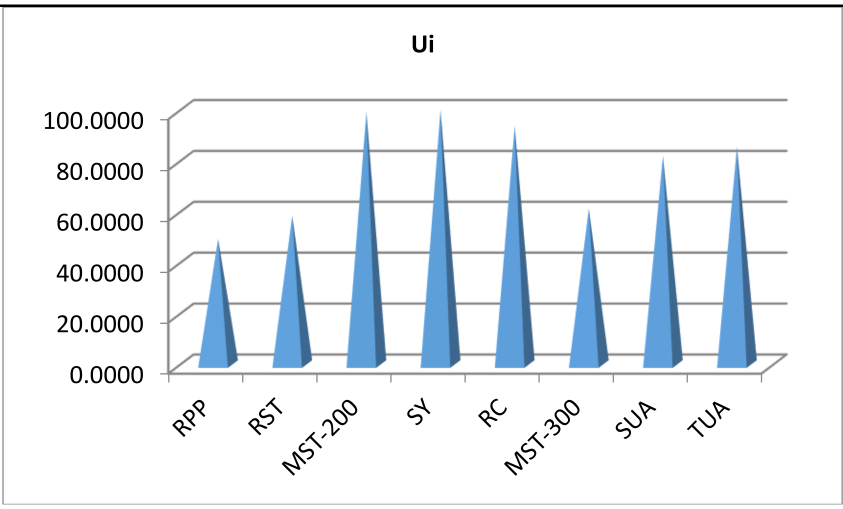

FIGURE 4. Ui values

Figure 4 depicts the calculation of Ui from Qi. The RPP Ui is 49.2251, the RST Ui is 58.3414, the MST-200 Ui is 99.1471, the SY Ui is 100.0000, the RC Ui is 93.6223, the MST-300 Ui is 61.1577, the SUA Ui is 81.8858, and the TUA Ui is 85.5138.

TABLE 8. Ranking

	Rank
RPP	8
RST	7
MST-200	2
SY	1
RC	3
MST-300	6
SUA	5
TUA	4

Table 8 shows that the SY is first, MST-200 is second, RC is third, and TUA is fourth, SUA is fifth, MST-300 is sixth, RST is seventh, and RPP is eighth.

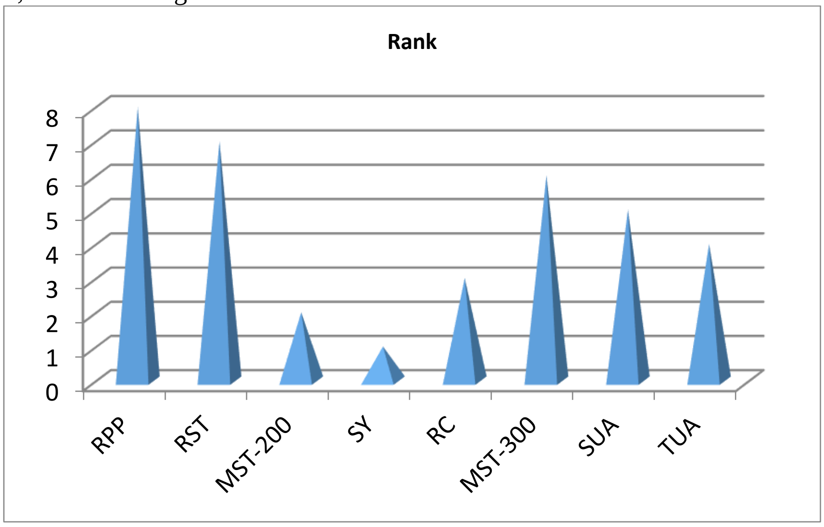

FIGURE 5. Ranking

Figure 5 shows that the SY is first, the MST-200 is second, the RC is third, and the TUA is fourth. The SUA is fifth, the MST-300 is sixth, the RST is seventh, and the RPP is eighth.

As can be seen, the final classification reveals substantial differences between RAMCAP and COPRAS results. According to RAMCAP's output, the risk value corresponds to a specific range, and values such as 7, 11, 13, 14, 17, 19, and 21 are never considered. Furthermore, from a computational standpoint, the conventional RAMCAP method has a reduced ability to define a precise and accurate ranking, then group critical assets into a few categories, and give similar rankings to different assets. This should take into consideration the fact that organizations are constrained by two major constraints: financial and time. Allocating resources to unnecessary tasks is a waste of time. Threat and outcome can have the same risk value despite having distinct impacts; however, the risk implication is not the same. Finally, the relative significance of C3, C4, and C5 is not taken into account. The following may not be true in real-world situations. As a result, the suggested model's outputs are more accurate. This can lead to a more exact, accurate, and robust risk assessment for security.

5. CONCLUSION

In response to the rapid growth of the defense industries and terrorists' growing ability to carry out damaging activities, particularly against vital infrastructure, administrations and responsible departments have given more time and attention to the need for asset regulations and risk measures. However, because risks and threats are intangible, it is challenging for decision makers to accurately and precisely measure risk. Most prior studies assessed risk solely using RAMCAP parameters. This paper introduces and develops a novel framework for risk evaluation in critical infrastructure. The proposed model extends the traditional RAMCAP by adding new parameters that affect the risk level to achieve a more precise categorization of existing risks. Due to the complexity of the suggested framework and the extant conflicting criteria, To address the ambiguity of the decision-making problem, a multi-criteria decision-making method based on COPRAS theory is described. Decision-makers can use this technique to specify the order of significance of criteria and make decisions based on linguistic variables. To demonstrate the method's possible applications, a case study is provided. A comparison of the suggested approach and traditional RAMCAP has been finished.

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