_____

# A Study on the Selection of Software Testing Techniques Based on the Multi-Criteria Decision-Making Model

**Quy-Tho Nhu**
School of Mechanical and Automotive Engineering
Hanoi University of Industry
Hanoi, Vietnam
e-mail: nhuquytho@haui.edu.vn

**Abstract**—In software development, software testing is a crucial activity that aims to ensure the quality and reliability of software products. However, the process of selecting the most appropriate software testing technique for a particular project can be a challenging and intricate task, as it involves multiple conflicting criteria and goals. This article suggests applying multi-criteria decision making (MCDM) methods, namely COPRAS, EDAS, and MABAC, to the challenge of selecting software testing techniques. Additionally, the weights of the criteria were analyzed using the MEREC method. The outcomes indicate that the methods employed consistently rank the options. The end-to-end testing technique is ranked the highest, while bottom-up integration testing is ranked the lowest. The ranking and selection approach proposed in the article can serve as a valuable tool for software testers and managers when making informed decisions about selecting software testing techniques that meet user requirements.

**Keywords**- Software testing; COPRAS; EDAS; MACBAC; MEREC

## I. INTRODUCTION

In the ever-evolving domain of software development, ensuring the delivery of top-notch software products holds significance. Software testing assumes a crucial role in this endeavor by identifying glitches and validating that the software fulfills the desired requirements. However, with a plethora of software testing techniques at hand, selecting the most appropriate one for a given scenario presents a significant challenge. Several factors, such as project nature, available resources, time limitations, and specific testing objectives, influence this decision. In such intricate circumstances, the multi-criteria decision-making (MCDM) method is commonly employed to solve the problem [1, 2]. Renowned for its effectiveness, this method is favored by many researchers when tackling selection problems with multiple criteria [3-5].

In [6], a comprehensive MCDM-based framework is presented for solving the general material selection problem using the COPRAS, TOPSIS, and DEA paradigms. In [7], a hybrid MCDM model combining SD and COPRAS methods is proposed to evaluate the performance of foreign deposit banks. Another study [8] applies MCDM and COPRAS methods to assess neglected areas in Vilnius city and identify 15 significant early indicators. Pitchipoo et al. [9] utilize the COPRAS decision model to optimize the blind spot in heavy vehicles by considering the design parameters of rear view mirrors. Additionally, the COPRAS method is used in [10] to select drill bits for drilling with high pressure coolant. In a different direction, Rashid and colleagues [11] employ the EDAS method for the selection of industrial robots based on distance from the average solution. In [12], the authors propose a novel GHF-EDAS method by combining previous references and developing a combined weighting method based on the minimum identification information principle. This method integrates GHF entropy and the method based on removal effects of criteria (MEREC). In [13], an attempt is made to solve a supplier selection problem in the textile industry by integrating interval rough number (IRN), the best worst method (BWM), and the evaluation based on distance from average solution (EDAS) method. Furthermore, the EDAS approach is proposed in [14] for the selection of cotton fabrics. Muravev et al. [15] utilize the BWM-MABAC model to select integrated suppliers. Nabeeh and colleagues [16] utilize the hybrid methodology of Bipolar Neutrosophic Linguistic Numbers (BNLNs) in BWM to calculate the significance weights of assessment criteria. They also present the MABAC method as an accurate approach to assess hospital serving. In another study, the MABAC method is applied to select transportation and resource handling at logistics centers [17]. Keshavarz-Ghorabaee et al. [18] utilized the MABAC method to assess the sustainability of public transport systems. Shanmugasundar et al. [19] adopted the MEREC method to select the optimal robot from a pool of twelve alternatives. They considered seven criteria, with payload, speed, and reach as beneficial criteria, while mechanical weight, repeatability, cost, and power consumption were treated as cost criteria. In another study [20], the authors employed the MEREC method for laptop selection.

This study focuses on the application of MCDM methods, namely COPRAS, EDAS, and MABAC, for making software testing choices. To enhance evaluation efficiency, the MEREC weighting method is also employed. The research and implementation will specifically concentrate on evaluating 8 criteria and selecting from 9 available options for software testing.

**2782**

_____

## II. MULTI-CRITERIA DECISION-MAKING METHOD

### A. COPRAS method

The COPRAS method is implemented to assess decision alternatives based on the following steps [8]:

Step 1: Calculate normalized decision matrix using equation:

$$X = [x_{ij}]_{m \times n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ x_{21} & \cdots & x_{2n} \\ \vdots & \cdots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

where $x_{ij}$ represents the element of the matrix corresponding to the $i^{th}$ choice and the $j^{th}$ criterion. The variables $m$ and $n$ represent the total number of options and criteria, respectively.

Step 2: Normalize the matrix according to the formula:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{2}$$

Step 3: Determine the decision matrix normalization value

$$\hat{r}_{ij} = r_{ij} w_j; i = 1,2,\dots,m; j = 1,2,\dots,n \tag{3}$$

where $w_j$ is the weight of criterion $j$.

Step 4: By considering positive or negative criteria, the maximum or minimum value for each criterion is determined using the following formula:

$$S_{+i} = \sum_{j=1}^{g} \hat{r}_{ij} \tag{4}$$

$$S_{-i} = \sum_{j=g+1}^{n} \hat{r}_{ij} \tag{5}$$

Here, $g$ represents the number of attributes that need to be maximized, while the remaining attributes from $g + 1$ to $n$ are preferred to have lower values.

Step 5: Calculate the relative significance of alternatives:

$$Q_i = S_{+i} + \frac{\min_i S_{-i} \sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{i=1}^{m} \frac{\min_i S_{-i}}{S_{-i}}} \tag{6}$$

Step 6: The final ranking is conducted based on the $H_i$ values.

$$H_i = \frac{Q_i}{Q_i^{max}} \tag{7}$$

The alternatives with higher $H_i$ values are considered to be better.

### B. EDAS method

The implementation steps for multi-criteria decision-making using the EDAS method are as follows [11]:

Step 1: Similar to step 1 of the COPRAS method.

Step 2: Calculate $AVG_j$:

$$AVG_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \tag{8}$$

Step 3: To determine the positive distance and negative distance from the average value, the following steps are taken. For profit-type criteria, negative and positive distances are calculated using equations (9) and (10) respectively. Conversely, for cost-type criteria, distances are calculated using formulas (11) and (12):

$$PD_{ij} = \frac{\max(0,(x_{ij}-AVG_j)}{AVG_j} \tag{9}$$

$$ND_{ij} = \frac{\max(0,(AVG_j-x_{ij})}{AVG_j} \tag{10}$$

$$PD_{ij} = \frac{\max(0,(AVG_j-x_{ij})}{AVG_j} \tag{11}$$

$$ND_{ij} = \frac{\max(0,(x_{ij}-AVG_j)}{AVG_j} \tag{12}$$

Step 4: The sum of the positive distance ($SP$) and the sum of the negative distance ($SN$) are calculated as follows:

$$SP_i = \sum_{i=1}^{m} w_j PD_{ij} \tag{13}$$

$$SN_i = \sum_{i=1}^{m} w_j ND_{ij} \tag{14}$$

where $w_j$ is the weight of criterion $j$.

Step 5: Calculate $NSP_i$ and $NSN_i$:

$$NSP_i = \frac{SP_i}{\max(SP_i)} \tag{15}$$

$$NSN_i = 1 - \frac{SN_i}{\max(SN_i)} \tag{16}$$

Step 6: Compute $G$ for each alternative is calculated using formula (18). A higher point value indicates a higher ranking for the alternative.

$$G_i = \frac{1}{2}(NSP_i + NSN_i) \tag{17}$$

### C. MABAC method

The ranking of options using the MABAC method is performed by following these steps [18]:

Step 1: The same the step 1 of COPRAS method.

Step 2: Calculate the normalization of the elements from the initial matrix:

$$x_{ij}^* = \frac{x_{ij}-x_i^-}{r_i^+ - r_i^-} \quad \text{for benefit type criteria} \tag{18}$$

$$x_{ij}^* = \frac{x_{ij}-x_i^+}{x_i^- - x_i^+} \quad \text{for cost type criteria} \tag{19}$$

The normalized value of the decision matrix for the $i^{th}$ choice at the $j^{th}$ criterion, denoted as $x_{ij}^*$, is calculated. Here, $x_i^+ = \max(x_1, x_2, \dots, x_m)$ represents the maximum value observed for the criterion among the alternatives, while $x_i^- = \min(x_1, x_2, \dots, x_m)$ represents the minimum value observed for the criterion among the alternatives.

**2783**

_____

Step 3: The normalized weight value of the matrix is determined using the following formula:

$$\hat{x}_{ij} = w_j + x^*_{ij} w_j \qquad (20)$$

Step 4: Finding the matrix for the border approximation area:

$$g_i = \left(\prod_{j=1}^{m} \hat{x}_{ij}\right)^{1/m} \qquad (21)$$

Step 5: Determining the distance of the alternative from the border approximation area for the matrix elements as follows:

$$q_{ij} = \hat{x}_{ij} - g_i; \quad i = 1, \ldots, m; j = 1, \ldots, n \qquad (22)$$

Step 6: Calculate the overall distance of each selection from the boundary of the approximate area matrix as follows:

$$S_i = \sum_{j=1}^{n} q_{ij}; \quad j = 1, \ldots, n; \; i = 1, \ldots, m \qquad (23)$$

Arrange the totals in descending order.

### D. MEREC weight method

Following these subsequent steps, the determination of criteria weights using the MEREC method is conducted [20]:

Step 1: The same the step 1 of COPRAS method.

Step 2: Determining the values of the elements in the normalized matrix using the following formula:

$$u_{ij} = \frac{\min x_{ij}}{x_{ij}} \quad \text{for benefit type criteria} \qquad (24)$$

$$u_{ij} = \frac{x_{ij}}{\max x_{ij}} \quad \text{for cost type criteria} \qquad (25)$$

Step 3: The overall efficiency of the alternatives is calculated using the following equation:

$$S_i = \ln\left(1 + \left(\frac{1}{m}\sum_j |\ln(u_{ij})|\right)\right) \qquad (26)$$

Step 4: Determining the efficiency of the $i^{th}$ choice, denoted as $S^*_{ij}$.

$$S^*_{ij} = \ln\left(1 + \left(\frac{1}{m}\sum_{k, k \neq j} |\ln(u_{ij})|\right)\right) \qquad (27)$$

Step 5: The absolute value of the deviations is determined using the following equation:

$$E_j = \sum_i |S^*_{ij} - S_i| \qquad (28)$$

Step 6: The equation below is used to calculate the ultimate weights of the criteria:

$$w_j = \frac{E_j}{\sum_k E_k} \qquad (29)$$

## III. RESULTS AND DISCUSSION

There are several integration testing techniques commonly used in software testing. These include Incremental Integration (II), Top-Down Integration Testing (TDI), Bottom-Up Integration Testing (BI), Sandwich (SA), Big Bang (BB), End-to-End Testing (E2E), High-Frequency Testing (HF), and Smoke Testing (SM) [21]. Table 1 is constructed to evaluate the applicable criteria. In the table, a score ranging from 1 to 5 is assigned to each criterion, representing the level: V = Very, M = Medium, L = Low, F = Fast, S = Slow, E = Easy, D = Difficult.

TABLE I.     LINGUISTIC TERMS AND VALUES CORRESPONDING TO THE CRITERIA

| Criteria | Acronym | Scales | | | | |
|---|---|---|---|---|---|---|
| | | 5 | 4 | 3 | 2 | 1 |
| Time when the basic functionality is exposed | C1 | VF | F | M | S | VS |
| Reusability of the test cases | C2 | VH | H | M | L | VL |
| End user view | C3 | VH | H | M | L | VL |
| Time of fault detection | C4 | VF | F | M | S | VS |
| Effort required in terms of the additional work to be done | C5 | VH | H | M | L | VL |
| Ease of fixing errors | C6 | VE | E | M | D | VD |
| Frequency of running the tests | C7 | VH | H | M | L | VL |
| Ease of writing the test cases | C8 | VE | E | M | D | VD |
| Possibility of automating the testing | C9 | VH | H | M | L | VL |

The following steps are undertaken to determine the best alternative among the mentioned options. The decision matrix, displaying the ranking of the $i^{th}$ alternative in relation to the $j^{th}$ criterion, is presented in Table 2.

TABLE II.     DECISION MATRIX

| Alternatives/ Criteria | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 |
|---|---|---|---|---|---|---|---|---|---|
| II | 3 | 4 | 1 | 3 | 4 | 5 | 3 | 4 | 3 |
| TDI | 5 | 4 | 4 | 5 | 3 | 4 | 3 | 4 | 1 |
| BI | 1 | 1 | 1 | 2 | 3 | 4 | 3 | 5 | 1 |
| SA | 5 | 3 | 2 | 4 | 3 | 4 | 2 | 3 | 1 |
| BB | 5 | 2 | 4 | 4 | 3 | 1 | 1 | 3 | 1 |
| E2E | 5 | 5 | 5 | 5 | 4 | 2 | 3 | 3 | 4 |
| HF | 3 | 3 | 1 | 5 | 4 | 5 | 5 | 3 | 5 |
| SM | 5 | 3 | 5 | 5 | 4 | 4 | 4 | 4 | 3 |

By applying the calculations of the MEREC method as outlined in section 2, the weighted value for each criterion is obtained, as illustrated in Figure 1.
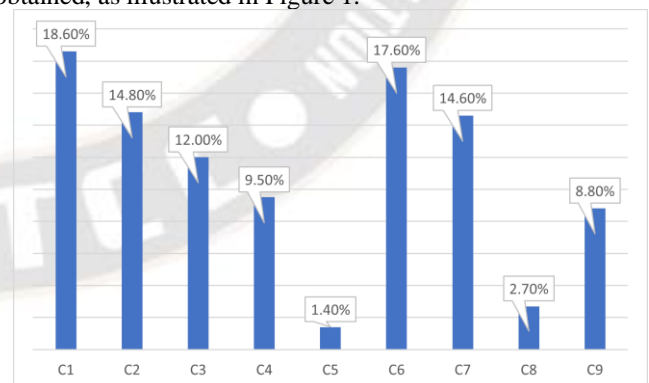


Figure 1.    The corresponding weight value for each criterion is determined according to the merec method.

The ranking of the best software testing technique is as follows:

TABLE III.     RESULTS OF RANKING THE OPTIONS

| Alternatives | COPRAS | EDAS | MABAC |
|---|---|---|---|
| II | 0.795 (5) | 0.5431 (5) | 0.1065 (5) |

**2784**

_____

| | | | |
|---|---|---|---|
| TDI | 0.906 (4) | 0.7255 (4) | 0.1273 (4) |
| BI | 0.491 (8) | 0.0464 (8) | -0.2477 (8) |
| SA | 0.737 (6) | 0.4261 (6) | -0.1019 (6) |
| BB | 0.609 (7) | 0.2501 (7) | -0.1956 (7) |
| E2E | 0.986 (2) | 0.9004 (1) | 0.2835 (1) |
| HF | 0.925 (3) | 0.8006 (3) | 0.221 (3) |
| SM | 1.0 (1) | 0.8958 (2) | 0.221 (2) |

Table 4 demonstrates a high level of consistency among the MCDM methods utilized. The rankings are mostly similar, with the exception of the EDAS and MABAC methods both ranking E2E as the best option (with SM ranking 2nd), while the COPRAS method ranks SM as the top option (with E2E ranking 2nd). Therefore, caution should be exercised when utilizing the COPRAS method to determine the best solution. E2E engineering tests offer self-contained testing with comprehensive functional solutions, eliminating the need for external assistance. This results in smoother, more convenient, less troublesome, and cost-effective processes. Conversely, BI is ranked the lowest due to its failure to consider the end user's perspective. These findings indicate that the proposed method has encompassed all the criteria for evaluating testing techniques and has generated appropriate results.

## IV. CONCLUSION

This research paper has investigated and provided ratings for popular software testing options based on 9 critical evaluation criteria in the field of software testing. The study's findings reveal the ranking order of techniques, from highest to lowest, as follows: End-to-End testing, Smoke testing, High-Frequency testing, Top-Down integration testing, Incremental Integration, Sandwich, Big bang, Bottom-up integration testing. The proposed method can be employed by software organizations to select the appropriate testing technique that ensures efficiency and meets practical requirements.

## REFERENCES

[1] T. V. Dua, "Application of multi-criteria decision-making method to choose rice harvester in Vietnam," EUREKA: Physics and Engineering, vol. 6, pp. 173-182, 2023.

[2] H. A. Bui, N. T. Tran, D. L. Nguyen, "Multi-criteria decision making in the powder-mixed electrical discharge machining process based on the cocoso, spotis algorithms and the weighting methods," International Journal of Modern Manufacturing Technologies, vol. XV, no. 1 / 2023, pp. 69-79, 2023.

[3] N. T. Tran, "Application of the multi-criteria analysis method MAIRCA, SPOTIS, COMET for the optimization of sustainable electricity technology development," EUREKA: Physics and Engineering, vol. 1 (2024), pp. 180–188, 2024.

[4] T. V. Dua, "Combination of design of experiments and simple additive weighting methods: a new method for rapid multi-criteria decision making," EUREKA: Physics and Engineering, vol. 1 (2023), pp. 120-133, 2023.

[5] D. D. Trung, N. T. Nguyen, D. V. Duc, "Study on multi-objective optimization of the turning process of en 10503 steel by combination of taguchi method and moora technique," EUREKA: Physics and Engineering, vol. 2, pp. 52-65, 2021.

[6] S. H. Mousavi-Nasab, A. Sotoudeh-Anvari, "A comprehensive MCDM-based approach using TOPSIS, COPRAS and DEA as an auxiliary tool for material selection problems," Materials & Design, vol. 121, pp. 237-253, 2017.

[7] Y. Aydin, "A hybrid multi-criteria decision making (MCDM) model consisting of SD and COPRAS methods in performance evaluation of foreign deposit banks," Equinox Journal of Economics Business and Political Studies, vol. 7, no. 2, pp. 160-176, 2020.

[8] B. Vytautas, B. Marija, P. Vytautas, "Assessment of neglected areas in Vilnius city using MCDM and COPRAS methods," Procedia Engineering, vol. 122, pp. 29-38, 2015.

[9] P. Pitchipoo, D. S. Vincent, N. Rajini, S. Rajakarunakaran, "COPRAS decision model to optimize blind spot in heavy vehicles: A comparative perspective," Procedia Engineering, vol. 97, pp. 1049-1059, 2014.

[10] J. Stanojkovic, M. Radovanovic, "Selection of drill for drilling with high pressure coolant using entropy and copras MCDM method," UPB Sci. Bull. Ser. D Mech. Eng, vol. 79, pp. 199-20, 2017.

[11] T. Rashid, A. Ali, Y. M. Chu, "Hybrid BW-EDAS MCDM methodology for optimal industrial robot selection," Plos one, vol. 16, no. 2, pp. 0246738, 2021.

[12] P. Liu, H. Wang, G. Wei, "EDAS method for multi-attribute decision-making with generalized hesitant fuzzy numbers and its application to energy projects selection," Journal of Intelligent & Fuzzy Systems, vol. 45, no. 2, pp. 2763-2779, 2023.

[13] A. Ulutaş, "Sewing machine selection for a textile workshop by using EDAS method," Journal of Business Research Turk, vol. 9, no. 2, pp. 169-183, 2017.

[14] A. Mitra, "Selection of cotton fabrics using EDAS method," Journal of Natural Fibers, vol. 19, no. 7, pp. 2706-2718, 2022.

[15] D. Muravev, N. Mijic, "A novel integrated provider selection multicriteria model: the BWM-MABAC model," Decision Making: Applications in Management and Engineering, vol. 3, no. 1, pp. 60-78, 2020.

[16] N. A. Nabeeh, A. Abdel-Monem, A. Abdelmouty, "A novel methodology for assessment of hospital service according to BWM, MABAC, PROMETHEE II," Neutrosophic Sets and Systems, vol. 31, no. 1, pp. 63-79, 2020.

[17] D. Pamučar, G. Ćirović, "The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC)," Expert systems with applications, vol. 42, no. 6, pp. 3016-3028, 2015.

[18] M. Keshavarz-Ghorabaee, M. Amiri, M. Hashemi-Tabatabaei, M. Ghahremanloo, "Sustainable public transportation evaluation using a novel hybrid method based on fuzzy BWM and MABAC," Open Transportation Journal, vol. 15, no. 1, pp. 31-46, 2021.

[19] G. Shanmugasundar, G. Sapkota, R. Čep, K. Kalita, "Application of MEREC in multi-criteria selection of optimal spray-painting robot," Processes, vol. 10, no. 6, pp. 1172, 2022.

[20] S. Yenilmezel, I. Ertuğrul, "Laptop selection with MEREC based WASPAS method," Business Economics and Management Research Journal, vol. 6, no. 1, pp. 18-27, 2023.

[21] M. Victor, N. Upadhyay, "Selection of Software Testing Technique: A Multi Criteria Decision Making Approach," In: Trends in Computer Science, Engineering and Information Technology. CCSEIT 2011, Communications in Computer and Information Science, vol. 204, pp. 453–462, 2011.