Vol. 08, No. 2 (2026) 827-834, doi: 10.24874/PES08.02.020

Proceedings on Engineering Sciences

www.pesjournal.net

COMPARISON OF MCMD METHODS FOR SELECTING SMALL GENERATORS

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Received 11.03.2026
Revised 29.04.2026
Accepted 04.06.2026

Keywords:

MCDM, FUCA method, CURLI method, generator selection

A B S T R A C T

In every fields, the selection of an option among many available options needs to be based on many parameters (called criteria). Multi-criteria decision-making (MCDM) methods were used more and more to solve these types of problems. This study was carried out to compare two MCDM methods with each other in the selection of small generators. FUCA and CURLI are the two MCDM methods that were motioned in this study. The comparison of these two methods were performed in many cases such as changing the number of options, changing the number of criteria (adding or subtracting). After performed all these scenarios, it was found that the ranks of generators types were completely the same when they were rank by the two methods FUCA and CURLI.

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1. INTRODUCTION

Nowadays, there are more than 200 *MCDM* methods proposed by scientists, they are being used a lot in many different fields (Baydaş et al., 2023). Many studies showed that the ranks of alternatives can be very different if they were ranked by different methods (Truong et al., 2023; Trung et al., 2024a). Therefore, in each specific case, the comparison of *MCDM* methods with each other was performed. When ranking life quality in some municipalities in Tehran (Iran), the *SAW* method was determined to have better quality than the three methods *TOPSIS*, *VIKOR*, and *ELECTRE* (Vakilipour et al., 2021). When ranking gas tungsten arc coating options, the *TOPSIS* method was determined to be better than the *MOORA* method (Ranjan et al., 2022). When ranking the best materials in sugar industry, the three methods *TOPSIS*, *MOORA*, and *COPRAS* were determined to be better than the *VIKOR* methods (Abou Iltaf Hussain et al., 2022). When ranking types of mobile phones, the *AHP* method was determined to be worse than the *BWM* method (Rezaei 2015), etc.

FUCA is the method that when it is used, the decision maker does not need to normalize data (Fernando et al., 2011). This is considered a difference of it when it is compared with other *MCDM* methods. The comparison of the *FUCA* method with some other methods was also performed in some studies. The best option for metal

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milling among nine identified options when using the *FUCA* method was also the same with when using the *TOPSIS* method. The best option for metal turning among twenty-seven options that were found when using the *FUCA* method was also the same with when using the *TOPSIS* and *SAW* methods. The best option for metal drilling was also found (among seventeen options) was coincidental with using the three methods including *FUCA*, *TOPSIS* and *COPRAS* (Do, 2022). In another study, when used to rank the financial performance of companies, the two methods *FUCA* and *PROMETHEE* were shown to be equally effective with each other and better and the eight methods including *TOPSIS*, *GRA*, *S-*, *WSA*, *SAW*, *COPRAS*, *MOORA* and *LINMAP* (Baydaş et al., 2022). When ranking the companies in the two periods before and after the Covid 19, the *FUCA* method was determined to be more effective than the *MOORA* and *MABAC* methods (Baydaş, 2022). The *FUCA* method was also confirmed to be better than the *TOPSIS* method when making multi-criteria decision in the selection of chemical manufacturing processes (Ouattara et al., 2012). Thus, the *FUCA* method was confirmed to be equally effective or better than the other *MCDM* methods. This gives a certain credibility to its use.

CURLI is a special *MCDM* method, this is the only method that when using it, the decision maker does not have to complete both the tasks of normalizing data and determining the weights for the criteria (Trung et. al., 2022; Trung et. al., 2024b). Therefore, this method is recommended when it is difficult to normalize the data or determine the weights for the criteria (Tran, 2022). The *CURLI* method determined the best option similar to when using the methods *EDAS*, *PROMETHEE*, *EXPROM2*, *TOPSIS*, and *VIKOR* in the selection of material to manufacture protective panels on cars, the material selection for gear manufacturing, and the material selection for cutting tools (Tran, 2022). In another study, the two methods *CURLI* and *R* determined the same best option when they were used to rank types of cars (Trung et. al., 2024b). In (Trung, 2022), the three methods including *CURLI*, *R* and *MABAC* all determined the same best option for bridge construction. Also in this study, it was shown that nine methods including *CURLI*, *R*, *SAW*, *WASPAS*, *TOPSIS*, *VIKOR*, *MOORA*, *COPRAS* and *PIV* all identified the same best alternative for metal turning. The fact that the *CURLI* method was proved to be equally effective with other *MCDM* methods in some studies mentioned above also creates a certain confidence for the use of this method.

The comparison of the two methods *CURLI* and *FUCA* was also performed in a few recent publications, such as in the selection of machine tools (Son et al., 2023), and the selection of air conditioners, washing machines and drones (Nguyen, 2023). In both of these studies, the best option determined when using the *FUCA* method was also the best option determined when using the *CURLI* method. However, in both of these studies, only the cases where criteria were quantitative were considered. A question that needs to be resolved is what will happen to the results of ranking the alternatives by the *FUCA* and *CURLI* methods if the criteria are qualitative and quantitative in a specific case. This study was carried out to answer this question in the case of selecting small generators. The reason that small generator was chosen as the experimental object in this study is based on its recent urgency. Recently, Vietnam's power grid has suffered from energy shortages due to water depletion in hydroelectric reservoirs. Electricity suppliers have to cut power periodically, which greatly affects people's daily activities. A solution that the leader has been implementing is to equip each family with a small generator. As the world becomes more challenging and competitors increasingly innovate, it is crucial for companies to adapt by embracing change and implementing a strategic plan to stay competitive (Onyekwere, 2024).

2. THE TWO USED MCDM METHODS

2.1 The FUCA method

Ranking the alternatives by the *FUCA* method needs to be done according to the following sequence (Fernando et al., 2011):

Step 1: Construct a decision matrix with *m* rows and *n* columns, where *m* and *n* are the number of alternatives that need to be ranked and the number of criteria for each alternative, respectively.

Step 2: For each criterion *j* (with $j = 1 \div n$), rank the calternatives. Let r_{ij} be the rank of alternative *i*, if the value of alternative *i* is the best among m alternatives, then $r_{ij} = 1$. In contrast, if the value of alternative i is the worst among m alternatives, then $r_{ij} = m$.

Step 3: Formula (1) is used to calculate the scores of alternatives.

$$v_i = \sum_{j=1}^{n} r_{ij} \times w_j \quad (1)$$

In (1), w_j is the weight of criterion *j*.
Step 4: The ranks of alternatives are arranged in ascending order of their scores.

2.2 The CURLI method

To rank alternatives when using the *CURLI* method, the following sequence needs to be followed (Trung et al., 2022).

Step 1: For each criterion, construct a square matrix of level m and score the alternatives.

The scoring of alternatives (for each criterion) is done as follows. For example, in the cell corresponding to column 1 and row 2, the value of the alternative 1 is better

than that of the alternative 2, then score 1 in that cell. Another example, if in the cell corresponding to column 2 and row 1, the value of the alternative 2 is worse than that of the alternative 1, then score -1 in that cell. As in another example, if in the cell corresponding to column 2 and row m, the value of alternative 2 is equal to that of alternative m then score 0, etc. Score 0 will also be filled in the cells that lie on the main diagonal of the matrix.

Step 2: The scoring matrix of the alternatives for all the criteria (called matrix Q) will be constructed by adding all the scoring matrices of the alternatives for each criterion together.

Step 3: Rearrange the Q matrix by changing the positions of the rows and the positions of the columns so that the number of cells with non-positive values that lie above the main diagonal of the matrix is maximum. After arranging, the order from top to bottom of the rows is the rank of the alternative in that row.

3. SELECTION OF GENERATOR BY USING MCDM METHODS

3.1 Types of small generator

An electronics store currently sells seven types of generators, among them, only one is made in Vietnam, the rest are imported from Korea. According to the documentation that comes with the machine, the list of criteria to describe each type of machine includes selling price, type of fuel for machine operation (gasoline or oil), continuous use time, cylinder capacity, power rating, length of machine, width of machine, height of machine, noise level while working, weight of the machine, and origin of machine. These criteria are denoted respectively from C1 to C12. Of course, the selection of generator not only consider these twelve parameters but also consider the other parameters such as warranty period, maintenance cost, after-sale customer service of the supplier, etc. but fortunately, these parameters share the same value for all seven machines under consideration. Therefore, the selection of generator only needs to consider the parameters that are not completely the same in all seven alternatives. The units and types of these criteria have been presented in the last two rows of Table 1. When being asked, most of the respondents said that they would prefer gasoline generators to oil generators. The reason for this is that gasoline generators work base on the process of compressing air and igniting spark plugs, so that starting a gasoline generator will be as simple as starting a motorbike. Meanwhile, oil generators use injectors, fuel is injected into the combustion chamber mixed with compressed air at high temperature and pressure, after that, the mixture spontaneously ignites and generates force for the engine to work. This working principle of oil generators make it more difficult to start than gasoline generators, especially on low temperature days. About the manufacturer's band, the general psychology of Vietnam customers is to prefer imported goods over domestic products, therefore, a generator that was made in Korea will make them more interested than in Vietnam.

Table 1. Types of generator

Type	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Hyundai HY30CLE	8.99	gasoline	10	96	2.3	2.6	610	490	490	74	54	Korea
Hyundai HY9000LE	23.9	gasoline	16	420	2.5	2.8	670	540	555	75	86	Korea
Hyundai HY7000LE	21.9	gasoline	22	389	5	5.5	670	540	555	75	82	Korea
Hyundai HY3100LE	11.9	gasoline	22	196	2.5	2.8	610	490	490	68	43	Korea
Hyundai DHY6000SE	38.9	oil	16	212	5	5.5	920	520	760	68	160	Korea
Hyundai DHY6000LE	35.45	oil	13	456	5	5.8	720	480	600	79	116	Korea
Hữu Toàn HG3100	17.31	gasoline	12	163	2	2.3	635	425	475	65	34	Viet Nam
Criteria type	Min	-	Max	Max	Max	Max	Min	Min	Min	Max	Max	-
Unit of criteria	Million VND	-	hour	cc	kW	kW	mm	mm	mm	dbA	kg	-

According to the data in Table 1, it can be seen that if the buyers only choose a machine with the lowest selling price (Hyundai HY30CLE), they will buy a machine with short continuous use time, small cylinder capacity, high noise level, etc. Another example, if the buyers buy a machine with high capacity (such as Hyundai HY7000LE), their product will have high selling price, high noise level, etc. Considering another example, if the buyers choose products made in Korea without considering the machine made in Vietnam (Hữu Toàn HG3100), they have forgotten the machine with the lowest noise level. Which means, it is impossible to buy the best product only base on one parameter. To choose the best type of machine, it is a need to consider all of twelve criteria in Table 1. That means choosing a generator is multi-criteria decision-making. This act will

be done with the help of the two methods *FUCA* and *CURLI*. The content will be presented in the next chapter of this article.

3.2 Applying the FUCA method

Rank r_{ij} of each machine type (for each criterion) was arranged according to the *FUCA* method and resulted in Table 2.

Applying the formula (1), scores v_i of the alternatives were calculated as in Table 3. The weights of the criteria were determined equally, which means each weight was equal to 1/12.

The ranks of the machines were also arranged according to their scores and the results were summarized in the last column of Table 3.

According to the results of ranking the alternatives in Table 3, the priority order when buying generators is Hyundai HY7000LE > Hyundai DHY6000LE > Hyundai HY3100LE > Hyundai HY9000LE > Hyundai HY30CLE > Hyundai DHY6000SE > Hữu Toàn HG3100.

Table 2. Rank of each machine type

Type	r_{ij}											
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
Hyundai HY30CLE	1	3	7	7	6	6	1.5	3.5	2.5	4	5	3.5
Hyundai HY9000LE	5	3	3.5	2	4.5	4.5	4.5	6.5	4.5	2.5	3	3.5
Hyundai HY7000LE	4	3	1.5	3	2	2.5	4.5	6.5	4.5	2.5	4	3.5
Hyundai HY3100LE	2	3	1.5	5	4.5	4.5	1.5	3.5	2.5	5.5	6	3.5
Hyundai DHY6000SE	7	6.5	3.5	4	2	2.5	7	5	7	5.5	1	3.5
Hyundai DHY6000LE	6	6.5	5	1	2	1	6	2	6	1	2	3.5
Hữu Toàn HG3100	3	3	6	6	7	7	3	1	1	7	7	7

Table 3. Scores and ranks of the alternatives

Type	$r_{ij} * w_j$												v_i	Rank
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12		
Hyundai HY30CLE	.0833	.2500	.5833	.5833	.5000	.5000	.1250	.2917	.2083	.3333	.4167	.2917	4.1667	5
Hyundai HY9000LE	.4167	.2500	.2917	.1667	.3750	.3750	.3750	.5417	.3750	.2083	.2500	.2917	3.9167	4
Hyundai HY7000LE	.3333	.2500	.1250	.2500	.1667	.2083	.3750	.5417	.3750	.2083	.3333	.2917	3.4583	1
Hyundai HY3100LE	.1667	.2500	.1250	.4167	.3750	.3750	.1250	.2917	.2083	.4583	.5000	.2917	3.5833	3
Hyundai DHY6000SE	.5833	.5417	.2917	.3333	.1667	.2083	.5833	.4167	.5833	.4583	.0833	.2917	4.5417	6
Hyundai DHY6000LE	.5000	.5417	.4167	.0833	.1667	.0833	.5000	.1667	.5000	.0833	.1667	.2917	3.5000	2
Hữu Toàn HG3100	.2500	.2500	.5000	.5000	.5833	.5833	.2500	.0833	.0833	.5833	.5833	.5833	4.8333	7

3.3 Applying the CURLI method

Step 1 of the *CURLI* method was applied to score the different types of machines (for each criterion). Table 4 shows the scoring results for the options with respect to the price criterion. For the remaining criteria, the scoring was done in a similar manner.

Applying step 2 of the *CURLI* method constructed in the Q matrix in Table 5.

Step 3 of the *CURLI* method was applied to swap the positions of rows and the positions of columns in the Q matrix, the results were presented in Table 6.

Table 4. Scoring machine types for price criterion

Type	S1	S2	S3	S4	S5	S6	S7
Hyundai HY30CLE	0	-1	-1	-1	-1	-1	-1
Hyundai HY9000LE	1	0	1	1	-1	-1	1
Hyundai HY7000LE	1	-1	0	1	-1	-1	1
Hyundai HY3100LE	1	-1	-1	0	-1	-1	-1
Hyundai DHY6000SE	1	1	1	1	0	1	1
Hyundai DHY6000LE	1	1	1	1	-1	0	1
Hữu Toàn HG3100	1	-1	-1	1	-1	-1	0

Table 5. Q matrix

Type	S1	S2	S3	S4	S5	S6	S7
Hyundai HY30CLE	0	2	2	1	-1	3	-3
Hyundai HY9000LE	-2	0	2	2	-2	1	-3
Hyundai HY7000LE	-2	-2	0	-1	-5	0	-3
Hyundai HY3100LE	-1	-2	1	0	-2	1	-7
Hyundai DHY6000SE	1	2	5	2	0	5	-2
Hyundai DHY6000LE	-3	-1	0	-1	-5	0	-2
Hữu Toàn HG3100	3	3	3	7	2	2	0

Table 6. The Q matrix were rearranged

Type	S3	S6	S4	S2	S1	S5	S7
Hyundai HY7000LE	0	0	-1	-2	-2	-5	-3
Hyundai DHY6000LE	0	0	-1	-1	-3	-5	-2
Hyundai HY3100LE	1	1	0	-2	-1	-2	-7
Hyundai HY9000LE	2	1	2	0	-2	-2	-3
Hyundai HY30CLE	2	3	1	2	0	-1	-3
Hyundai DHY6000SE	5	5	2	2	1	0	-2
Hữu Toàn HG3100	3	2	7	3	3	2	0

According to the results in Table 6, the ranks of generator types can be seen in the priority order from top to bottom, which means Hyundai HY7000LE is the best type, on the contrary, Hữu Toàn HG3100 is the worst type. Thus, when applying the two methods *FUCA* and *CURLI*, the same results were obtained, that Hyundai HY7000LE is the best machine type, in contrast, Hữu Toàn HG3100 is the worst type. On the other hand, it can be seen that the ranks of generators were completely coincidental when using the two methods *FUCA* and *CURLI*.

3.4 Ranking the generators according to different cases

In addition to the first case that has just been performed, the second case is made where the buyer does not care about the origin of the product, but only care about the price and specifications of the product.

The act of ranking the generators by the two methods *FUCA* and *CURLI* was also done, the results were shown in the chart of Figure 1.

In this case, the ranks of the generators are completely coincidental when using the two methods *FUCA* and *CURLI*. Hyundai HY7000LE was still determined to be the best machine type, and Hữu Toàn HG3100 was still determined to be the worst machine type.

The third case that was made is that the buyer does not care about the type of fuel for machine operation. Ranking the machine types in this case was also done by using the two methods *FUCA* and *CURLI*, the results were presented in the chart of Figure 2.

In this case, the ranks of the generators are still coincidental when using the two methods *FUCA* and *CURLI*. In this case, the best type of generator is Hyundai HY6000LE. Once again, Hữu Toàn HG3100 is determined to be the worst machine type.

The fourth case that is made is that the buyers only choose products with the same origin. That means they only choose Korean-made generators. It is also assumed that all twelve criteria shown in the documentation that came with the machines are considered by them. Choosing the best machine type in this case requires considering only six types. The two methods *FUCA* and *CURLI* were once again used to solve this problem, the results of ranking six types of Korean-made generators were presented in the chart of Figure 3.

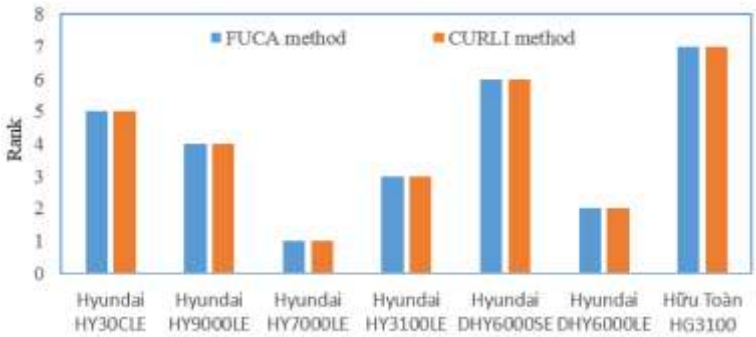


Figure 1. Ranking the generators without considering manufacturer brand

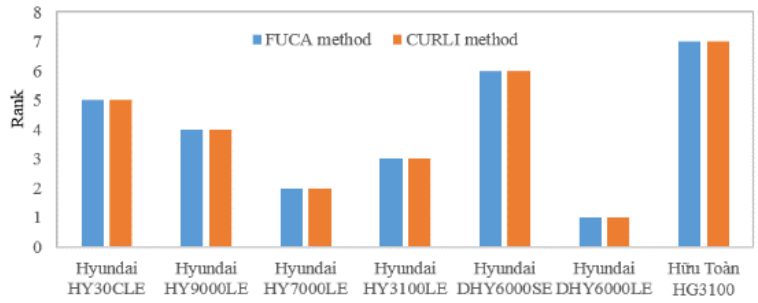


Figure 2. Ranking the generators without considering type of fuel for machine operation

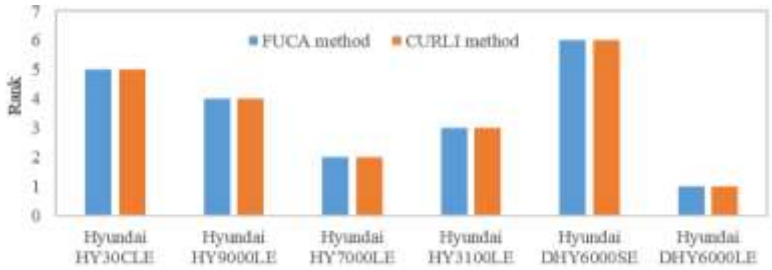


Figure 3. Ranking the generators originating from Korea

In this case, once again, we can see that the ranks of the generators are completely coincidental when they are ranked by two different methods, *FUCA* and *CURLI*. Among six Korean-made generators, Hyundai HY6000LE is still determined to be the best alternative.

Another hypothetical situation is that the warranty period for each machine type is not completely the same. It should be reiterated that the hypothetical situation is only for comparing the two methods *FUCA* and *CURLI*, but in reality, the warranty period for the seven alternatives is the same. Suppose the warranty period for the products Hyundai HY30CLE, Hyundai HY7000LE, Hyundai DHY6000SE and Hữu Toàn HG3100 is 12 months, the warranty period for the remaining three products is 6 months. Then, the ranking of alternatives must consider thirteen criteria, including twelve criteria available in the documentation that comes with the machines and criterion of warranty period. The two methods *FUCA* and *CURLI* were once again used in this case, the results were presented in the chart of Figure 4.

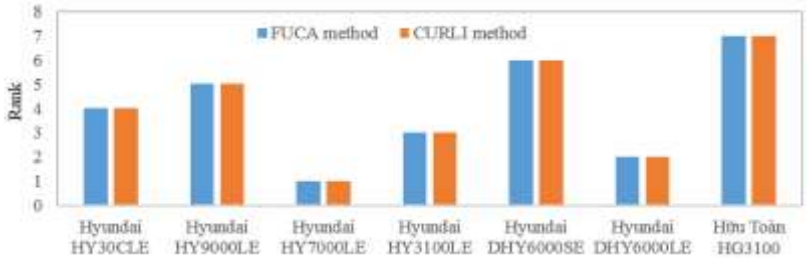


Figure 4. Ranking the generator types assuming the warranty period of the products is not the same

With this hypothetical situation, we still find that the ranks of the generators are exactly the same when they are ranked by two different methods, *FUCA* and *CURLI*.

Through all of the above cases, we have an overview that the two methods *FUCA* and *CURLI* gave the results of ranking the alternatives are completely coincidental when they are used to rank generators.

4. CONCLUSION

The two methods *FUCA* and *CURLI* are used for the first time to rank generator types in this study. Many cases were made to compare these two methods. Some conclusions are drawn as follows:

- The best type of generator determined by the two methods *FUCA* and *CURLI* are the same. Not only that, the ranks of the remaining generators are completely coincidental when using these two methods. Even more special, this happened in all the cases that were done.

- Among seven types of generators introduced by the supplier, Hyundai HY7000LE is identified as the best.

- In this study, when using the *FUCA* method, we only consider the case where the weights of the criteria are

equal. In case the weight of the criteria is determined by another method (such as the Entropy method, the *MEREC* method, the *AHP* method, the *CRITIC* method, the *PIPRECIA* method,…), then how the ranks of the alternatives will be changed.. To answer this question, more studies need to be done in the future.

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