MULTI-CRITERIA DECISION-MAKING FOR ELECTRIC BICYCLE SELECTION

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Abstract:
Electric bicycle is a vehicle which is used widely in all the citys and provinces of Vietnam. However, it's hard to choose "the most suitable" or "the best" type of electric bicycle because each type has different criteria (parameters). To choose out the best option, we need to consider all the alternatives at once. That is called multi-criteria decision-making. This research used three multi-criteria decision-making methods include *SAW* method, *MARCOS* method and *PSI* method to choose from seven best-selling types of electric bicycle on the market in 2022. All the methods which were used chose out the same best electric bicycle type and the same worst bicycle type. And so, among seven types of electric bicycle which include M133 mini, M133 Sport 2022, Aima 133AM, Nijia – PA4, DK 133M, Yadea iGo and Yadea i3, the best type is Aima 133AM, in contrast, Yadea iGo is considered the worst type. Things that need to be done in the folowing researches were proposed in the last part of this paper.

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1. INTRODUCTION

Nowadays, electric bicycle became one of the most prioritized vehicles used in all over Vietnam. This type of vehicle is considered suitable for many classes of people, many ages. Using electric bicycles not only reduce the pollution level, the rate of accidents compared to motobikes, but also increase users health. On the other hand, in the context of many changes in gasoline prices in the world, electric bicycle is known as an significant solution in saving money for moving activities. From this fact, in recent years, there are many types of electric bicycle represented on the market to satisfy customers. However, because of that, customers may be confused about choosing a type that is considered the most suitable. We can say so because if a customer want to choose an electric bicycle, there will be many parameters (criteria) that need to be considered, such as price, vehicle load, charging time, the distance that bicyce can go after each charge, maximum speed, etc. Nevertheless, the values of the parameters in each electric bicycle type are not the same, sometimes constradictory, for example, a bicycle which has low price, may have low maximum speed or low vehicle load. An electric bicycle selection based on subjective opinions of a customer about a random alternative may lead to to unsuitable selection. Multi-Criteria Decision-Making (*MCDM*) to choose the best alternative from the available alternatives is a task in all different areas. Choosing a type of electric bicycle from many available types on the market, therefore, need to apply this technique as well. Up to this time, no studies have been found that have done this.

Through the time, many different *MCDM* methods were proposed by scientists such as: Simple Additive Weighting *(SAW)*, Measurement Alternatives and Ranking according to Compromise Solution *(MARCOS)*, Preference selection index *(PSI)*, Weighted Aggregates Sum Product Assessment

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(WASPAS), Multiobjective Optimization On the basis of Ratio Analysis *(MOORA)*, COmplex PRroportional ASsessment *(COPRAS*), Technique for Order Preference by Similarity to Ideal Solution *(TOPSIS)*, etc. In certain conditions, using these methods may give different results. Therefore, to make sure an alternative is considered the best alternative, scientists usually use more than one method simultaenously [1].

Ranking to select the best electric bicycle in this research is done by using 3 different methods, including *SAW* method, *MARCOS* method, *PSI* method. The reason these methods are used is:

SAW is known as the oldest method (1964), it is considered the foundation for Sientists to propose other methods [1]. It is also considered a widely used method because of its simplicity [2-6]. For the reason, the method may be oldest, but it is still used in the recent researches, such as: evaluating flood control projects [7], air-conditioner selection [8], school selection [9, 10], evaluating national football teams participating in the 2018 World Cup [11], selecting students to receive grants [12], recruiting University teachers [13], ranking teachers of a secondary school [14], ranking singers of a band [15], assessing the sustainability of real estate [16], industrial robot selection, flexible manufacturing systems (FMS) selection, and non-traditional machining methods selection [17], etc.

MARCOS is a method that was found recently (2020) [18] with many proven advantages: high stability in ranking alternatives, possibility to determine the best solution regardless of the number of alternatives and weight determination method [19]. This method is also used widely to rank alternatives in many different areas: ranking project management softwares [20], ranking the quality of electronic services in the aviation industry [21], ranking planes for domestic flights in Turkey [22], ranking logistics efficiency of countries [23], ranking efficiency of railway systems [24], ranking forklift [25], ranking refractory supplier in the iron and steel industry in India [26], etc.

PSI is a method proposed in 2018 with a special feature which is different from *SAW* method and MARCOS method, this method does not need to determine weights for criteria [27]. This method is also used to rank the alternatives in many different areas: evaluating performances of machines [28], offering a plam to recover waste from electical/electronic products [29], choosing a method to develop an automated system in selecting students who are eligible for scholarship [30], making decisions in choosing materials to recover/beautify teeth [31], choosing the life cycle design option of the production system [32], making selection for technological parameters for the turning process [33], choosing the parameters for the spark machining process [34], choosing the parameters for the grinding process [35], ranking the efficiency of production chains [36], ranking materials for engineering [37], ranking individuals who are eligible for credit loans in Indonesia [38], selecting a location for old computer store [39], comparing the tourism potential of several countries [40], selecting machine in manufacturing companies [41], etc.

Using three different *MCDM* methods with different features (*SAW* – the oldest method, *MARCOS* – the method which was found recently and *PSI* – the method does not need to determine weights for criteria) for the purpose of making the results of ranking the alternatives in the most objective way. This is a new feature of this study compared with other published papers. The steps to rank the alternatives according to these three methods are presented in the second part of the paper. The ranking of electric bicycles is presented in the third part of this study. The discussion about the results and the conclusions drawn is the last content to end this study.

2. SOME MULTI-CRITERIA DECISION MAKING METHODS

2.1. SAW method

The steps for implementation of multi-criteria decision-making according to the *SAW* method are as follows [42]:

Step 1: Build a decision matrix with *m* alternatives ($A_1 \div A_m$) and *n* criteria ($C_1 \div C_n$) as the table 1. If the criterion is the larger the better, it is called a B type criterion. In contrast, if the criterion is the smaller the better, it is called a C type criterion. Where y_{ij} denotes the performance value of i^{th} alternative on j^{th} criterion.

Step 2: Calculate the normalized decision matrix by using the following formula.

$$n_{ij} = \frac{y_{ij}}{\max y_{ij}} \quad if\ j \in B \tag{1}$$

$$n_{ij} = \frac{\min y_{ij}}{y_{ij}} \quad if\ j \in C \tag{2}$$

Table 1. Decision matrix

Alternatives	C_1	C_2	C_j	C_{n-1}	C_n
A_1	y_{11}	y_{12}	y_{1j}	y_{1n-1}	y_{1n}
A_2	y_{21}	y_{22}	y_{2j}	y_{2n-1}	y_{2n}
A_i	y_{i1}	y_{i2}	y_{ij}	y_{in-1}	y_{in}
A_{m-1}	y_{m-11}	y_{m-12}	y_{m-1j}	y_{m-1n-1}	y_{m-1n}
A_m	y_{m1}	y_{m2}	y_{mj}	y_{mn-1}	y_{mn}

Step 3: Calculate criteria functions of the alternatives V_i.

$$V_i = \sum_{j=1}^{n} w_j \cdot n_{ij} \quad (3)$$

Where w_j is the weight of the criterion j.

Step 4: Rank the alternatives according to the rule that the alternative with the highest V_i is considered the best.

2.2. MARCOS method

The steps for implementation of multi-criteria decision-making according to the *MARCOS* method are as follows [18]:

Step 1: Similar to Step 1 of *SAW* method.

Step 2: Adding the ideal (*AI*) and anti-ideal solution (*AAI*) to the initial decision-making matrix to create an extended initial matrix.

$$Y = \begin{array}{c} AAI \\ A_1 \\ A_2 \\ \vdots \\ A_m \\ AI \end{array} \begin{bmatrix} y_{aa1} & \cdots & y_{aan} \\ y_{11} & \cdots & y_{1n} \\ y_{21} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots \\ y_{m1} & \cdots & y_{mn} \\ y_{ai1} & \cdots & y_{ain} \end{bmatrix} \quad (4)$$

Wherein:

- If $j \in B$

$AAI = min\,(y_{ij})$; $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$.

$AI = max\,(y_{ij})$; $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$.

- If $j \in C$

$AAI = max\,(y_{ij})$; $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$.

$AI = min\,(y_{ij})$; $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$.

Step 3: Normalizing the expanded initial matrix by using the following formula.

- If $j \in C$

$$u_{ij} = \frac{y_{AI}}{y_{ij}} \quad (5)$$

- If $j \in B$

$$u_{ij} = \frac{y_{ij}}{y_{AI}} \quad (6)$$

Step 4: Creating a weighted normalized matrix by using the following formula.

$$c_{ij} = u_{ij} \cdot w_j \quad (7)$$

Step 5: Determining the utility degree of alternatives K_i^+ và K_i^- by using the following formula:

$$K_i^- = \frac{S_i}{S_{AAI}} \quad (8)$$

$$K_i^+ = \frac{S_i}{S_{AI}} \quad (9)$$

Where:

S_i, S_{AAI} and S_{AI} represent the sum of the values of c_{ij}, y_{aai} and y_{ai}, where $i = 1, 2, \ldots, m$.

Step 6: Calculate the functions $f(K_i^+)$ and $f(K_i^-)$ according to the formula:

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (10)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (11)$$

Step 7: Calculating the function $f(Ki)$ of the alternatives according to the formula.

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}} \quad (12)$$

Step 8: Rank the alternatives according to the rule that the alternative with the highest $f(K_i)$ is considered the best.

2.3. PSI method

The steps for implementation of multi-criteria decision-making according to the *PSI* method are as follows [27].

Step 1: Similar to Step 1 of *SAW* method.

Step 2: The data normalization.

- If $j \in B$

$$n_{ij} = \frac{y_{ij}}{max y_{ij}} \quad (13)$$

- If $j \in C$

$$n_{ij} = \frac{min y_{ij}}{y_{ij}} \quad (14)$$

Step 3: Calculate the average values of the normalized data.

$$n = \frac{1}{n}\sum_{i=1}^{n} n_{ij} \quad (15)$$

Step 4: Determine the preference value.

$$\varphi_j = \sum_{i=1}^{n}\left[n_{ij} - n\right]^2 \quad (16)$$

Step 5: Determine the deviation of the preference value.

$$\emptyset_j = \left[1 - \varphi_j\right] \quad (17)$$

Step 6: Determine overall preference value.

$$\beta_j = \frac{\emptyset_j}{\sum_{j=1}^{m} \emptyset_j} \quad (18)$$

Step 7: Calculate the selection index θ_i for each criteria.

$$\theta_j = \sum_{j=1}^{m} n_{ij} \,.\, \beta_j \quad (19)$$

Step 8: Rank the alternatives according to the rule that the alternative with the highest θ_i is considered the best.

3. MULTI-CRITERIA DECISION MAKING FOR ELECTRIC BICYCLE

3.1. Parameters of electric bicycle

To choose out the type of electric bicycle which is considered "the best", we need to consider many parameters (also called criteria to evaluate each electric bicycle type) such as price, maximum speed, charging time, etc. Table 2 presents the basic parameters of seven best-selling types of electric bicycle in 2022 [43].

Seven available types of bicycle to choose include (Fig. 1) [43]:
Alternative 1 (*A1*): M133 mini electric bicycle;
Alternative 2 (*A2*): M133 Sport 2022 electric bicycle;
Alternative 3 (*A3*): Aima 133AM electric bicycle;
Alternative 4 (*A4*): Nijia electric bicycle;
Alternative 5 (*A5*): DK 133M electric bicycle;
*Alternative 6 (*A6*):* Yadea iGo electric bicycle;
Alternative 7 (A7): Yadea i3 electric bicycle.

Ten criteria used to evaluate for each type:
Criterion 1 (*C1*): Price (đ);
Criterion 2 (*C2*): Distance (km/1 charge);
Criterion 3 (*C3*): Charging time (hour);
Criterion 4 (*C4*): Maximum speed (km/h);
Criterion 5 (*C5*): bicycle weight (kg);
Criterion 6 (*C6*): bicycle load (kg);
Criterion 7 (*C7*): Saddle height (mm);
Criterion 8 (*C8*): Overall length of bicycle (mm);
Criterion 9 (*C9*): Overall width of bicycle (mm);
Criterion 10 (*C10*): Overall height of bicycle (mm).

Among ten criteria mentioned above, *C1* and *C3* are C type criteria, in opposition, the other criteria are B type criteria.

Table 1 presents the criteria of each electric bicycle type [43].

A1) M133 mini

A2) M133 Sport 2022

A3) Aima 133AM

A4) Nijia

A5) DK 133M

A6) Yadea iGo

A7) Yadea i3

Fig.1. Some electric bicycle types [43]

The parameters in Table 2 show that it is very hard to determine an alternative that ensures both *C1* and *C3* are absolutely smallest and the other alternatives (*C2*, *C*4, *C*5, *C6*, *C7*, *C8*, *C9* and *C10*) are absolutely largest. Some examples will prove that the statement is correct.

For example, the alternative *A1* shows that: *C1* is the smallest; *C3* is also the smallest (equal to *C*3 of the alternatives from *A2* to *A6*); *C4* is the largest (equal to *C4* of the alternatives from *A2* to *A5*); *C5* is the largest; *C7* is the largest (equal to *C7* of the alternatives from *A2* to *A5*). But *C2* of *A1* is smaller than *C2* of the alternatives *A3*, *A4* and *A5*; *C6* of *A1* is smaller than *C6* of the alternatives *A3*, *A4* and *A5*; *C8* of *A2* is smaller than *C8* of the alternatives *A3*, *A4* and *A5*; *C9* of *A1* is smaller than all the others *C9*; *C10* of *A1* is also smaller than *C10* of the alternatives from *A1* to *A6*.

Another example, the alternative *A2* shows that: *C3* is the smallest; other criteria *C4*, *C7*, *C8* and *C10* are the largest. But *C1* of *A2* is larger than *C1* of *A1*; *C2* of *A2* is smaller than *C2* of the alternatives from *A3* to *A5*; *C5* of *A2* is smaller than *C5* of *A1*; *C6* of *A2* is smaller than *C6* of the alternatives *A1*, *A3*, *A4* and *A5*; *C9* of *A2* is smaller than *C9* of *A6* and *A7*.

After considering all the other alternatives, the results are not different, which means, it is not possible to choose out an alternative which can be considered "the best" only base on the parameters from Table 2. To solve this problem, it is necessary to apply mathematical tools to choose the best alternative. *SAW* method, *MARCOS* method and *PSI* method will be used one after another to rank the electric bicycle types. However, determining the weights of criteria must be done before ranking the alternatives.

Table 2. Some parameters of electric bicycle [43]

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	7500000	45	7	35	56	160	750	1593	635	1015
A2	7900000	45	7	35	50	150	750	1640	640	1200
A3	9900000	50	7	35	50	180	750	1640	640	1200
A4	9900000	50	7	35	46	180	750	1640	640	1200
A5	11500000	50	7	35	52	180	750	1640	640	1200
A6	13990000	45	7	30	45	75	550	1550	650	1040
A7	13990000	45	8	30	45	75	600	1530	750	1000

3.2. Determining the weights of criteria

To choose an alternative that is considered the best among alternatives, at first, we have to determine the weights of the criteria used to evaluate the alternatives [1]. Determining the weights of criteria can be done by different methods: according to the subjective opinion of the decision maker, calculating the weights of criteria by using the *EQUAL* method, the *RS* method, the *ROC* method, the *ENTROPY* method, the *MEREC* method, the *APH* method, etc. This study used the simplest mthod to calculate the weights of criteria, *EQUAL* method.

EQUAL method is a weighting method done by using the following formula [44].

$$w_j = \frac{1}{n} \quad (20)$$

Where, *n* is the number of criteria.

Calculating the weights of the criteria from *C1* to *C10* of Table 2 by using *EQUAL* method according to the formula (20) and we have the result:

$$w_1 = w_2 = \cdots = w_8 = w_9 = w_{10} = \frac{1}{10} = 0.1$$

3.3. Applying the SAW method

Construct a decision matrix, this matrix is the table of the seven electric bicycle types (Table 2).

Applying the formulas (1) and (2) to determine the normalized values of the parameters in Table 3.

Table 3. Normalized values of the parameters according to SAW method

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	1.000	0.900	1.000	1.000	1.000	0.889	1.000	0.971	0.847	0.846
A2	0.949	0.900	1.000	1.000	0.893	0.833	1.000	1.000	0.853	1.000
A3	0.758	1.000	1.000	1.000	0.893	1.000	1.000	1.000	0.853	1.000
A4	0.758	1.000	1.000	1.000	0.821	1.000	1.000	1.000	0.853	1.000
A5	0.652	1.000	1.000	1.000	0.929	1.000	1.000	1.000	0.853	1.000
A6	0.536	0.900	1.000	0.857	0.804	0.417	0.733	0.945	0.867	0.867
A7	0.536	0.900	0.875	0.857	0.804	0.417	0.800	0.933	1.000	0.833

Table 4. V_i values of the alternatives and rank of the alternatives

Alternatives	V_i	Rank
A1	0.9453	2
A2	0.9429	5
A3	0.9504	1
A4	0.9432	4
A5	0.9434	3
A6	0.7925	7
A7	0.7955	6

Applying the formula (3) to calculate the values of V_i and the results are in Table 4. The results of ranking the alternatives according to V_i are presented in the table.

3.4. Applying the MARCOS method

Construct a decision matrix, this matrix is the table of the seven electric bicycle types (table 2).

Applying the formulas (4), (5) and (6) to determine the normalized values of the parameters in Table 5.

The weighted normalized values of the criteria are calculated by using the formula (7) and we get the results in Table 6.

The parameters K_i^+, K_i^-, $f(K_i^-)$, $f(K_i^+)$ and $f(K_i)$ are calculated correspondingly by the formulas (8), (9), (10), (11) and (12), and we get the results in Table 7. The results of ranking the alternatives according to the values of $f(K_i)$ are also presented in this table.

Table 5. Normalized values of the parameters according to MARCOS method

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	0.536	0.900	0.875	0.857	0.804	0.417	0.733	0.933	0.847	0.833
A2	1.000	0.900	1.000	1.000	1.000	0.889	1.000	0.971	0.847	0.846
A3	0.949	0.900	1.000	1.000	0.893	0.833	1.000	1.000	0.853	1.000
A4	0.758	1.000	1.000	1.000	0.893	1.000	1.000	1.000	0.853	1.000
A5	0.758	1.000	1.000	1.000	0.821	1.000	1.000	1.000	0.853	1.000
A6	0.652	1.000	1.000	1.000	0.929	1.000	1.000	1.000	0.853	1.000
A7	0.536	0.900	1.000	0.857	0.804	0.417	0.733	0.945	0.867	0.867

Table 6. Weighted normalized values of the parameters according to MARCOS method

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	0.100	0.090	0.100	0.100	0.100	0.089	0.100	0.097	0.085	0.085
A2	0.095	0.090	0.100	0.100	0.089	0.083	0.100	0.100	0.085	0.100
A3	0.076	0.100	0.100	0.100	0.089	0.100	0.100	0.100	0.085	0.100
A4	0.076	0.100	0.100	0.100	0.082	0.100	0.100	0.100	0.085	0.100
A5	0.065	0.100	0.100	0.100	0.093	0.100	0.100	0.100	0.085	0.100
A6	0.054	0.090	0.100	0.086	0.080	0.042	0.073	0.095	0.087	0.087
A7	0.054	0.090	0.088	0.086	0.080	0.042	0.080	0.093	0.100	0.083

Table 7. Other parameters in MARCOS and rank of the alternatives

Alternatives	K_i^+	K_i^-	$f(K_i^-)$	$f(K_i^+)$	$f(K_i)$	Rank
A1	1.25958×10^{-7}	6.75488×10^{-8}	0.6509	0.3491	3.74449×10^{-14}	2
A2	1.2564×10^{-7}	6.73785×10^{-8}			3.72563×10^{-14}	5
A3	1.26638×10^{-7}	6.79135×10^{-8}			3.78503×10^{-14}	1
A4	1.25686×10^{-7}	6.74031×10^{-8}			3.72835×10^{-14}	4
A5	1.25709×10^{-7}	6.74156×10^{-8}			3.72973×10^{-14}	3
A6	1.05604×10^{-7}	5.66337×10^{-8}			2.63212×10^{-14}	7
A7	1.05997×10^{-7}	5.68443×10^{-8}			2.65173×10^{-14}	6

3.5. Applying the PSI method

Construct a decision matrix, this matrix is the table of the seven electric bicycle types (Table 2).

Applying the formulas (13) and (14) to determine the normalized values of the parameters in Table 8.

Applying the formulas (15), (16) and (17) to determine the values of φ_j and $\varnothing_j$ in Table 9.

Applying the formulas (18) and (19) to determine the values of θ_i in Table 10. The results of ranking the alternatives according to the values of θ_i are also presented in this table.

Table 8. Normalized values of the parameters according to the PSI method

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A1	1.865	0.900	1.000	1.000	1.000	0.889	1.000	0.971	0.847	0.846
A2	1.771	0.900	1.000	1.000	0.893	0.833	1.000	1.000	0.853	1.000
A3	1.413	1.000	1.000	1.000	0.893	1.000	1.000	1.000	0.853	1.000
A4	1.413	1.000	1.000	1.000	0.821	1.000	1.000	1.000	0.853	1.000
A5	1.217	1.000	1.000	1.000	0.929	1.000	1.000	1.000	0.853	1.000
A6	1.000	0.900	1.000	0.857	0.804	0.417	0.733	0.945	0.867	0.867
A7	1.000	0.900	0.875	0.857	0.804	0.417	0.800	0.933	1.000	0.833

Table 9. Values of φ_j and $\varnothing_j$ of the criteria according to the PSI method

Parameters	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
φ_j	0.706	0.017	0.013	0.029	0.032	0.423	0.080	0.005	0.018	0.040
$\varnothing_j$	0.294	0.983	0.987	0.971	0.968	0.577	0.920	0.995	0.982	0.960

Table 10. Values of θ_i of the alternatives and rank of the alternatives

Alternatives	θ_i	Rank
A1	0.9728	5
A2	0.9750	4
A3	0.9854	1
A4	0.9774	3
A5	0.9827	2
A6	0.8468	7
A7	0.8497	6

And so, ranking the electric bicycle types according to the *SAW* method, M*ARCOS* method and *PSI* method is done. Table 11 is the results of ranking the electric bicycle types according to these three methods. To make it easy to observe the results, the values in Table 11 are showed on a chart like Fig. 2.

By observing the results in Table 11 and Fig. 2, we can see:

Table 11. Ranking the electric bicycle types according to three different methods

Alternatives	SAW	MARCOS	PSI
A1	2	2	5
A2	5	5	4
A3	1	1	1
A4	4	4	3
A5	3	3	2
A6	7	7	7
A7	6	6	6

- The ranking results according to *SAW* method and *MARCOS* method are the same.

- Although the ranking results according to the *PSI* method have some differences compared to the other methods (*SAW* and *MARCOS*), but all three of them show that *A3* is ranked first (the best one), *A7* ranked sixth ,and *A6* ranked seventh (the worst one). So we can come to a conclusion that *A3* is the best alternative, and *A6* is the worst one. In other words, among seven electric bicycle types mentioned in this study, Aima 133AM is the best electric bicycle type, and on the contrary, Yadea iGo is the worst electric bicycle type.

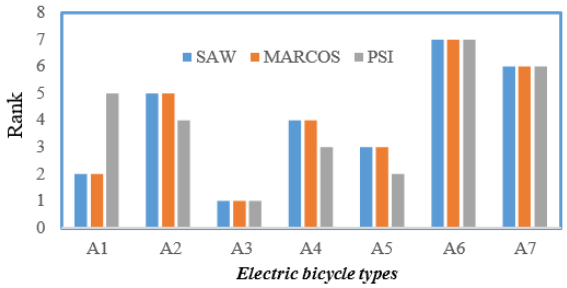

Fig. 2. Ranking electric bicycle types according to three different methods

4. CONCLUSION

When choosing an electric bicycle type, we need to consider about many factors such as the price of the bicycle, the charging time, the distance the bicycle can go after each charge, the speed of the bicycle, etc. This is a complicated thing to do and it is really easy to make mistakes if the choosing is done based on the subjective opinion of the customer only. To make sure that customers do not make mistakes, it is a need to use mathematical tools for electric bicycle type selection. Seven electric bicycle types which were mentioned in this study include M133 mini, M133 Sport 2022, Aima 133AM,Nijia – PA4, DK 133M,Yadea iGo and Yadea i3. Three mathematical methods used in this study are *SAW* method, *MARCOS* method and *PSI* method. The ranking results showed that Aima 133AM is the best type, in opposition, Yadea iGo is the worst type.

The alternatives were ranked while the weights of the criteria were equal. If the weights of the criteria were determined by another method (Entropy, *MEREC*, *ROC*, *RS*, ect.) or according to the customers opinions, the ranking results would be different. However, the method used in this study is believed to make the right choice when choosing the best alternative in accordance with each weighting method.

The criteria for evaluating electric bicycles used in this study are quantitative criteria. Some qualitative criteria have not been considered in this study such as battery type, color, driving safety, charging safety, etc. have not been mentioned in this study. Ranking electric bicycle types will be more complete when those criteria are considered. For qualitative criteria, using *PIPRECIA* (PIvot Pairwise RElative Criteria Importance Assessment) method [45] for determining the weights of the criteria is a solution that should be used.

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