Similarities and Differences between the Ranking Schemes of the WSM, TOPSIS AND VIKOR Multi Criteria Decision making methods in Software Product Selection

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Abstract: Three different sets of software selection data were applied to the three Multi Criteria Decision Making (MCDM) methods: Weighted Sum Average (WSA), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Multi-Criteria Optimization and Compromise Solution (VIKOR), with the objective of knowing if they will all recommend the same software product and produce the same ranking schemes. Results show that their ranking schemes are only 65% similar indicating that relying on only one MCDM method may lead to choosing the wrong software product which may have detrimental consequences.

Keywords: Software Product Selection, Multi Criteria Decision Making, Weighted Sum Method (WSM), TOPSIS, VIKOR.

I. INTRODUCTION

Software is used today by almost everyone. Businesses and organizations rely on software for their success. For any kind of software need, there are several options to choose from making it a difficult task, [1]. It becomes imperative that proper evaluation of the available software products is done and the most appropriate software product with the best quality is selected [2]. To choose the best alternative, several characteristics and sub characteristics, must be considered. This can be formulated as a multi-criteria decision making (MCDM) problem. Multi-criteria decision making comprises a finite set of alternatives, amongst which the decision-makers have to select, evaluate or rank according to the weights of a finite set of criteria (attributes)[3].To ensure that the chosen software product is accepted by all parties, it is necessary to use Standards based processes. The ISO/IEC 25010 Software Product Quality Standard and the ISO/IEC 25040 Software Product Evaluation Process Standard are applied in this study.

A. Aim and Objectives

The aim of the study is to compare the ranking schemes of three MCDM methods: WSM, TOPSIS and VIKOR to know if all three methods will propose the same software product for adoption, given the same set of data and produce the same ranking schemes. The objectives are to form the hierarchy of the software product model using ISO/IEC 25010[4]as basis and to perform the evaluation following the processes outlined in ISO/IEC 25040[5].

II. LITERATURE REVIEW

In [6] theyperformed a comparison of five MCDM method: ELECTRE, AHP, WSM, TOPSIS, and PROMETHEE on the Integrated Rehabilitation Prioritization to assess their suitability to be used in integrated asset management of water systems and found that the results of the different methods were not equal. In [7] they performed a comparison of three MCDM methods WSA, TOPSIS and MAPPAC (Multi-criteria Analysis of Preferences by means of Pair Actions and Criteria comparisons) on the area of e Government development to demonstrate their potential use and to evaluate the current state of e Government in EU countries with the aim of generating an overall ranking of the examined alternatives on the basis of a synthesis of their different approaches.

In [8] performed a comparison of multi criteria decision making the MCDM methods TOPSIS, VIKOR and ELECTRE to assess their ability of evaluating the performance of 21 food firms and concluded that all three methods can be used for the ranking firms' financial performances. In the comparative study of AHP, TOPSIS and PROMETHEE performed by [9], they concluded that some decision-making methods are still faced with the dilemma of subjectivity and that decision makers should put forward the feasibility of the method to be used in solving a particular problem.

III. METHODOLOGY

Figure 1 shows the hierarchy of the system that was built for the comparison using ISO/IEC 25010 as basis. The evaluation process followed the analyse, specify, design, perform and report evaluation processes of ISO/IEC 25040 as shown in Figure 2. Random numbers were generated to act as weights for each sub-characteristic.

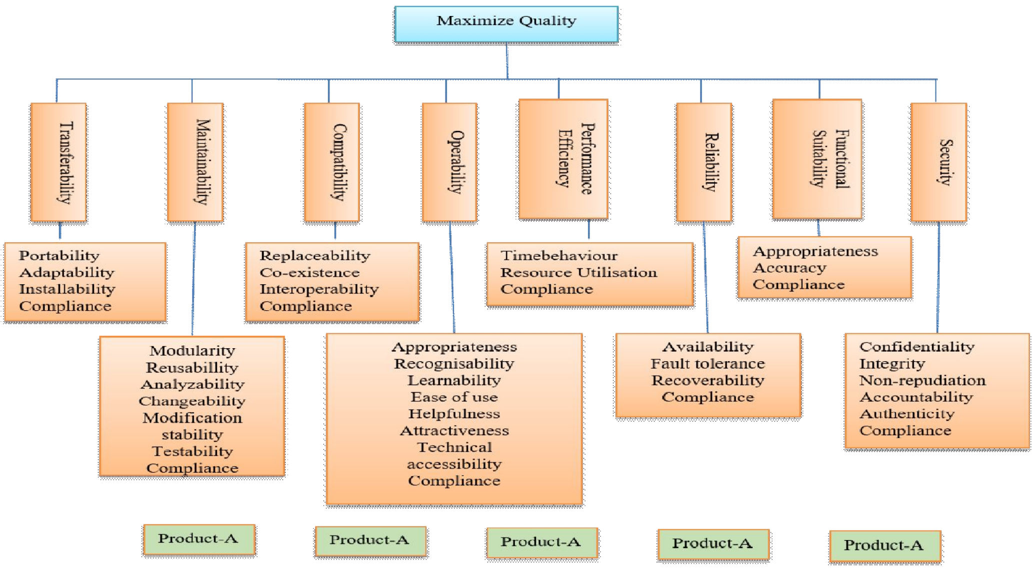

Figure 1: ISO/IEC 25010 - Software Product Quality Evaluation Process Reference Model

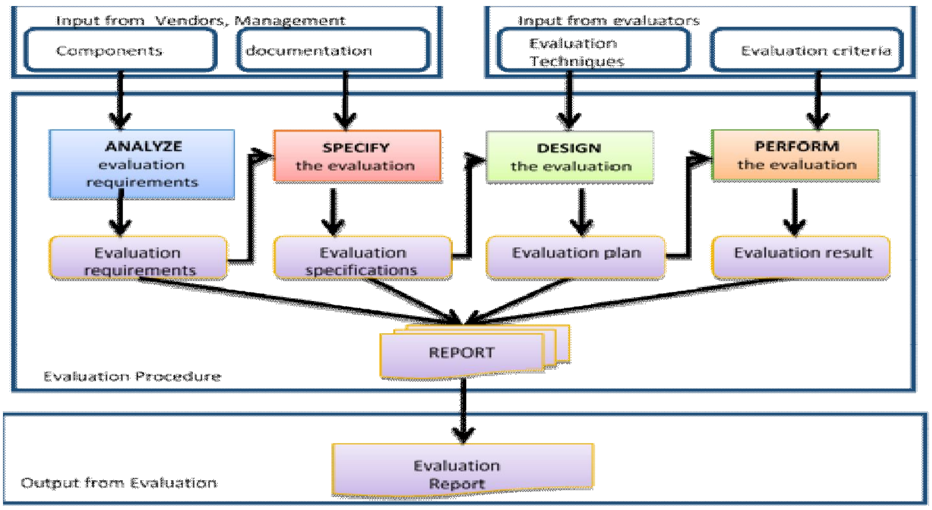

Figure 2: ISO/IEC 25040 - Software Product Quality Evaluation Process Reference Model

(A) The Comparison Algorithm

Description: The main steps of the algorithm used for the comparisons of the software products.
Input: Null
Output: The decision matrix with normalized weights for each sub-characteristic and scores for each product against each sub-characteristic, that will serve as into for the other methods.
Step 1: Start
Step 1: Form the hierarchy of the decision making process from ISO/IEC 25010 characteristics and sub-characteristics with the objective of maximizing the quality of the chosen software product.
Step 2: Identify the number of products to include in the evaluation.
Step3: Generate random numbers to form the decision maker's weight for each sub-characteristic.
Step 4: Form the normalized weight vector for the experiments
Step 5: Generate random numbers to form the matrix of the decision maker's final scores for each product against each sub-characteristic.
Step 6: Form the decision matrix for the Comparisons combining the vector in step 4 and the matrix in step 5
Step 6: Simultaneously apply WSM, TOPSIS and VIKOR steps to the Matrix in step 6
Step 7. Compare the results
Step 8: End

(B) Algorithm for the Weighted Sum Method

Description: WSM ranks alternatives by finding the product of the normalized weights of sub-characteristics and product values
Input: The decision matrix from the main algorithm with normalized weights for each sub-characteristic and scores for each product against each sub-characteristic.
Output: The ranking result showing the relative score of the alternatives and their rank among the alternatives.
1. Start
2. Obtain weight of each characteristic from the decision matrix.
3. Obtain scores of each software product against each characteristic from the decision matrix
4. Apply WSM steps.
4.1 For each product find the weighted score for each characteristic as follows:

*WS = Product Score (PS) * Characteristic Weight(CW).* (1)

4.2 For each product: Find the sum of all weighted scores (SWS).

$$SWS = \sum_{i=1}^{N} CWi \qquad (2)$$

4.3For each Product: Divide the sum of weights in 4.2 by the total number of characteristics (N).
4.4Find the rank of each product in descending order.
4.5Perform the final rank (The product with the highest score is best alternative.
5. Stop

(C)Algorithm for the TOPSIS Method

Description: The TOPSIS Algorithm finds the relative distances from the positive and negative ideal solutions and ranks as best the software product with the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS).
Input: 1. The decision matrix from the main algorithm with normalized weights for each sub-characteristic and scores for each product against each sub-characteristic.
Output: The ranking result showing the relative score of the alternatives and their rank among the alternatives.
1. Start
2. Obtain weight of each characteristic from the decision matrix.
3. Obtain scores of each software product against each characteristic from the decision matrix.
4. For each sub characteristic:
4.1. Find the best score (max)
4.2 Find the worst score (min)
4.3 Find the normalized score as follows
4.3.1 Find the square of product score
4.3.1 Find the sum of all squared product scores within the characteristic.
4.3.1 Find the square root of 4.3.2 above.
5. Form the normalized matrix by multiplying each product's score by the normalized score of each Sub-characteristic from step 4.3.
6. Form the weighted normalized matrix by multiplying each product's normalized matrix value with its initial score.

7. For each sub-characteristic find the Positive Ideal (PI) as the highest product score (find MAX).
8. For each sub-characteristic find the Negative Ideal (NI) as the lowest product score (find MIN). (Note: TOPSIS requires that all characteristics be benefits and does the conversion at this stage but this not required in this work as all characteristics are assumed benefits)
9. For each software product, compute the distance from Positive ideal by subtracting its weighted normalized score (step 6) from the positive ideal score (PI) of each sub-characteristic.
10. For each software product, compute the distance from negative ideal by subtracting the negative ideal score (NI) of each sub-characteristic from its weighted normalized score (in step 6).
11. For each product compute the di^+ = distance from ideal solution as follows:
11.1. Find the square of its distance from positive ideal score (from 10) for all sub characteristics.
11.2. Find the sum of all the squares in 11.1.
11.3. Find the square root of the sum of squares in 11.2.

$$D_i^+ = \sqrt{\sum_{j=1}^{n} W_j\,(a_{ij}^+ - a_{ij})^2} \quad (3)$$

12. For each product compute the di^- = distance from negative ideal solution as follows:
12.1. Find the square of its distance from the negative ideal score (from 11) for all sub characteristics.
12.2. Find the sum of all the squares in12.1.
12.3. Find the squares root of the sum of squares in 12.2.

$$D_i^- = \sqrt{\sum_{j=1}^{n} W_j\,(a_{ij} - a_{ij}^-)^2} \quad (4)$$

13. For each product compute C_i as follows:
13.1. Sum of di^+ and di^- from 11.3 and 12.3.
13.2. Divide di^- by the sum from 13.1.
14. Find the rank of each product in descending order.
15. For each product, perform the rank (the product with the highest is the best alternative.
16. Stop.

(D) VIKOR Method

Description: The VIKOR method ranks alternatives by a similarity measure, much like TOPSIS but is sometimes seem to be a more effective technique. It produces three ranking lists. Rank by S, R and Q

Input: 1. The decision matrix from the main algorithm with normalized weights for each sub-characteristic and scores for each product against each sub-characteristic.

Output: The ranking result showing the relative score of the alternatives and their rank among the alternatives.
1. Start
2. Obtain weight of each characteristic from the decisions matrix.
3. Obtain scores of each software product against each characteristic from the decision matrix.
4. For each sub-characteristic compute the following
4.1 F^* = the largest score (MAX).
4. 2 F^0 = the smallest score (MIN)
4.3 D = F* - F-
5. For each product: compute the distance from ideal solution as follows:
5.1 Find the difference between F- and the product's initial score for each sub-characteristic.
5.2 Divide the result from 5.1 by the difference from 4.3.
6. For each product: Compute the weighted distances from the ideal solution as by multiplying its distance from ideal (from 5.2) by its initial score for each sub characteristic.
7. Compute the utility value S_i of each product across all sub-characteristics by finding the sum of weighted distances from ideal solution.

$$S_i = \sum_{j=1}^{n} (W_j\,[W_j \frac{(f_{ij}^+ - f_{ij})}{(f_{ij}^+ - f_{ij}^-)}]) \quad (5)$$

8. Compute the regret value R_i of each product by finding the largest weighted distance from ideal.

$$Ri = MAX\left[[W_j \frac{(f_{ij}^+ - f_{ij})}{(f_{ij}^+ - f_{ij}^-)}]\right] \quad (6)$$

9. Compute the positive ideal as min (S). S is the solution from 7 the positive ideal compute S^* = min (s). The least of the sum of weighted distances from the ideal solution.
10. Compute the negative ideals S^- = max (s)
11. Compute $S^- - S^*$
12. From R in 7 find R^* = MIN (R)
13. From R in 7 find R^- = MAX (R)
14. Compute $R^- - R^*$

14.1 Perform ranking of all product alternatives by S.
14.2 Perform ranking of all product alternatives by R.
15 Compute Q in the following steps
15.1 $Q1 = 0.5 * (S - S^*) / (S^- - S^*)$
15.2 $Q2 = 0.5 * (R - R^*) / (R^- - R^*)$
15.3 Complete Q = Q1 + Q2
16. Find the rank of each product in ascending order.
17. Perform sensitivity tests
18. Stop.

IV. RESULTS

The decision matrix for dataset-1 is shown in the Table 1. The other decision tables are similar to this. The sets of results from the three datasets are shown from Tables 2 to 4

Table1: A Typical Decision Table for Each of the Datasets

Decision Matrix for Dataset-1						
	Normalized Weight	P1	P2	P3	P4	P5
Functional Completeness	0.03759	95	57	6	20	69
Functional Correctness	0.04373	80	60	17	57	77
Functional Appropriateness	0.03872	14	29	31	29	49
Time-behaviour	0.03888	71	57	83	6	66
Resource utilization	0.04978	29	66	57	37	49
Capacity	0.03579	83	17	60	9	9
Coexistence	0.05444	6	51	46	43	46
Interoperability	0.06747	49	77	57	60	3
Appropriateness Recognisability	0.02124	6	57	57	20	83
Learnability	0.02275	86	86	17	83	63
Operability	0.02189	29	91	74	83	49
User error protection	0.02346	34	37	57	49	66
User Interface Aesthetics	0.01719	29	46	94	6	49
Accessibility	0.02131	69	86	20	51	20
Maturity	0.03207	63	77	69	29	74
Availability	0.03842	20	66	60	23	49
Fault Tolerance	0.03098	51	71	46	26	9
Recoverability	0.02502	17	9	60	83	17
Confidentiality	0.02699	63	86	29	23	29
Integrity	0.02238	6	20	69	46	17
Non-Repudiation	0.02321	29	11	60	57	60
Accountability	0.03004	29	26	23	20	49
Authenticity	0.02266	17	26	60	60	49
Modularity	0.01342	77	97	9	20	17
Reusability	0.03196	57	51	66	60	23
Analyzability	0.02101	66	57	20	9	83
Modifiability	0.0276	29	69	9	34	57
Testability	0.03087	6	74	31	57	60
Adaptability	0.04799	60	34	91	57	20
Installability	0.04235	3	57	51	49	60
Replaceability	0.0388	51	57	57	86	66
	1					

Table 2: Results from Application of WSM, TOPSIS and VIKOR to Dataset-1

Results from Dataset-1					
TOPSIS	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
ci	0.546212	0.631999	0.579944	0.19973	0.355581
RANK	3	1	2	5	4
	Prod-B	Prod-C	Prod-A	Prod-E	Prod-D
Final Rank	Prod-B >> Prod-C >> Prod-A >> Prod-E >> Prod-D				
VIKOR	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
	0.107531	0	0.112376	1	0.851772
RANK	2	1	3	5	4
	Prod-B	Prod-A	Prod-C	Prod-E	Prod-D
Final Rank	Prod-B >> Prod-A >> Prod-C >> Prod-E >> Prod-D				
WSM	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
	0.301331	0.334066	0.322662	0.097838	0.157538
RANK	3	1	2	5	4
	Prod-B	Prod-C	Prod-A	Prod-E	Prod-D
Final Rank	Prod-B >> Prod-C >> Prod-A >> Prod-E >> Prod-D				

Table 3: Results from Application of WSM, TOPSIS and VIKOR to Dataset-2

Results from Dataset-2					
TOPSIS	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
ci	0.470438	0.65206	0.548766	0.306759	0.395006
RANK	3	1	2	5	4
	Prod-B	Prod-C	Prod-A	Prod-E	Prod-D
Final Rank	Prod-B >> Prod-C >> Prod-A >> Prod-E >> Prod-D				
VIKOR	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
	0.526168	0	0.425103	0.962534	0.884188
RANK	3	1	2	5	4
	Prod-B	Prod-C	Prod-A	Prod-E	Prod-D
Final Rank	Prod-B >> Prod-C >> Prod-A >> Prod-E >> Prod-D				
WSM	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
	0.265411	0.352921	0.311533	0.168917	0.218599
RANK	3	1	2	5	4
	Prod-B	Prod-C	Prod-A	Prod-E	Prod-D
Final Rank	Prod-B >> Prod-C >> Prod-A >> Prod-E >> Prod-D				

Table 4: Results from Application of WSM, TOPSIS and VIKOR to Dataset-3

Results from Dataset-3					
TOPSIS	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
ci	0.473825	0.569405	0.550691	0.49284	0.512715
RANK	5	1	2	4	3
	Prod-B	Prod-C	Prod-E	Prod-D	Prod-A
Final Rank	Prod-B >> Prod-C >> Prod-E >> Prod-D >> Prod-A				
VIKOR	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
	0.765706	0	0.649483	0.294336	0.667592
RANK	5	1	3	2	4
	Prod-B	Prod-D	Prod-C	Prod-E	Prod-A
Final Rank	Prod-B >> Prod-D >> Prod-C >> Prod-E >> Prod-A				
WSM	Prod-A	Prod-B	Prod-C	Prod-D	Prod-E
	0.288996	0.340379	0.322113	0.294837	0.319515
RANK	5	1	2	4	3
	Prod-B	Prod-C	Prod-E	Prod-D	Prod-A
Final Rank	Prod-B >> Prod-C >> Prod-E >> Prod-D >> Prod-A				

V. DISCUSSION

The results obtained show that for the same set of data, the three MCDM methods applied may produce different ranking results. Figure 3 to 5 Show the ranking result from the Datasets. From dataset one, VIKOR and WSM produced the same ranking result but TOPSIS swaps their first and second position. All other ranks were in agreement. From dataset two, we observe that all three MCDM methods produce the same final ranking. From dataset three, we observe that TOPSIS and WSM gave the same final ranking but VIKOR's was different for the 2nd, 3rd and 4th place. Table 5 shows the summary of the ranking agreements from the three datasets.

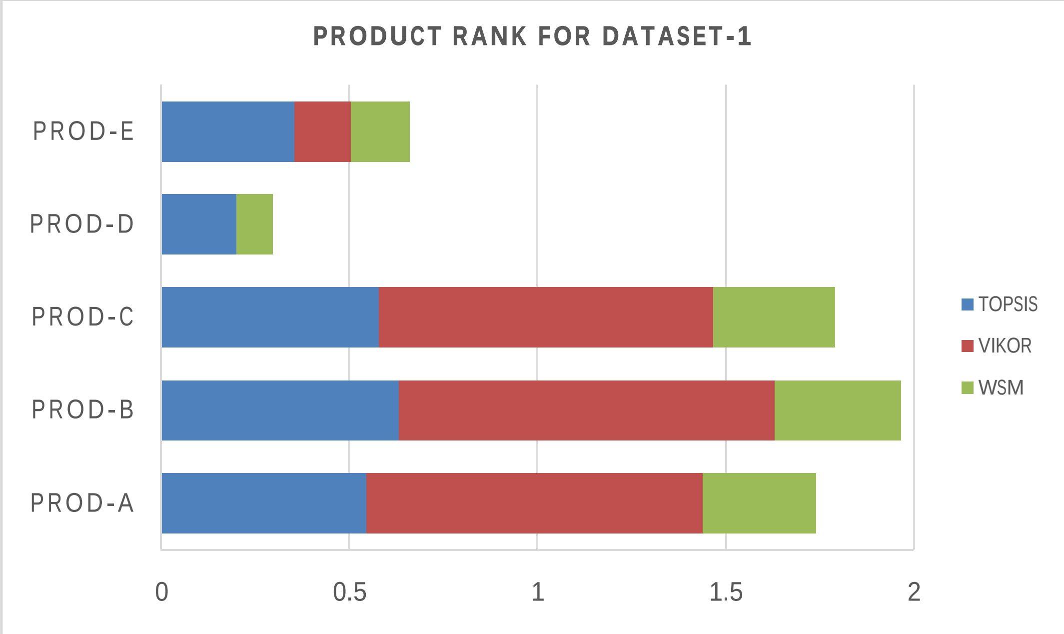

Figure 3: Showing the ranking order from Dataset 1

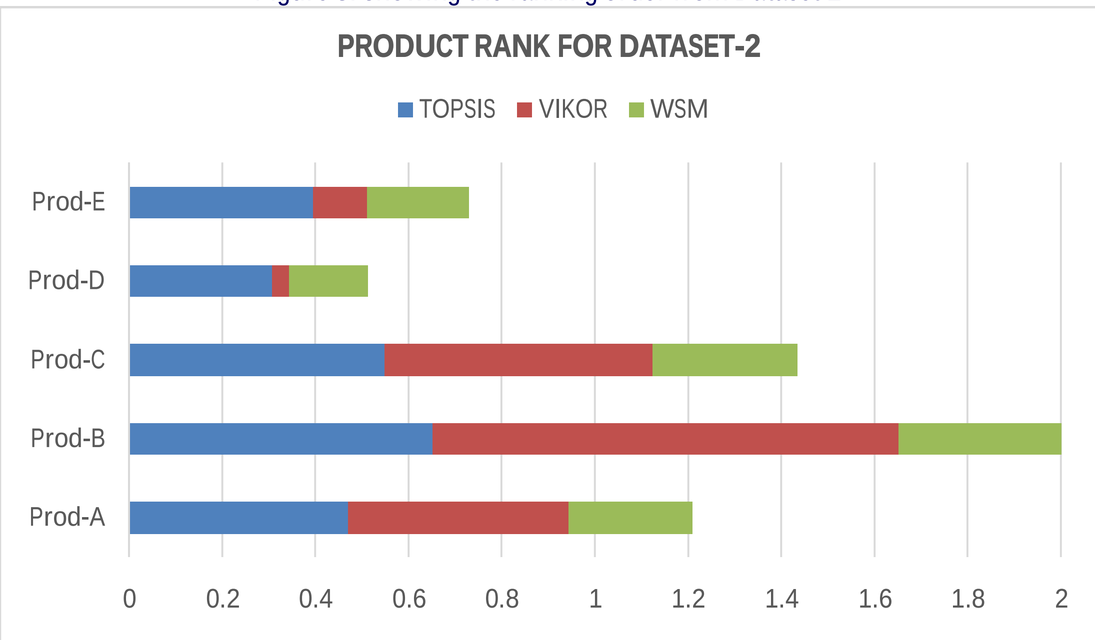

Figure 4: Ranking of alternatives from Dataset 2

Table 5: SUMMARY OF RESULTS FROM THE THREE DATASETS

	1st	2nd	3rd	4th	5th
Dataset-1	All Agree	Not Agree	Not Agree	All Agree	All Agree
Dataset-2	All Agree	All Agree	All Agree	All Agree	All Agree
Dataset-3	All Agree	Not Agree	Not Agree	Not Agree	All Agree

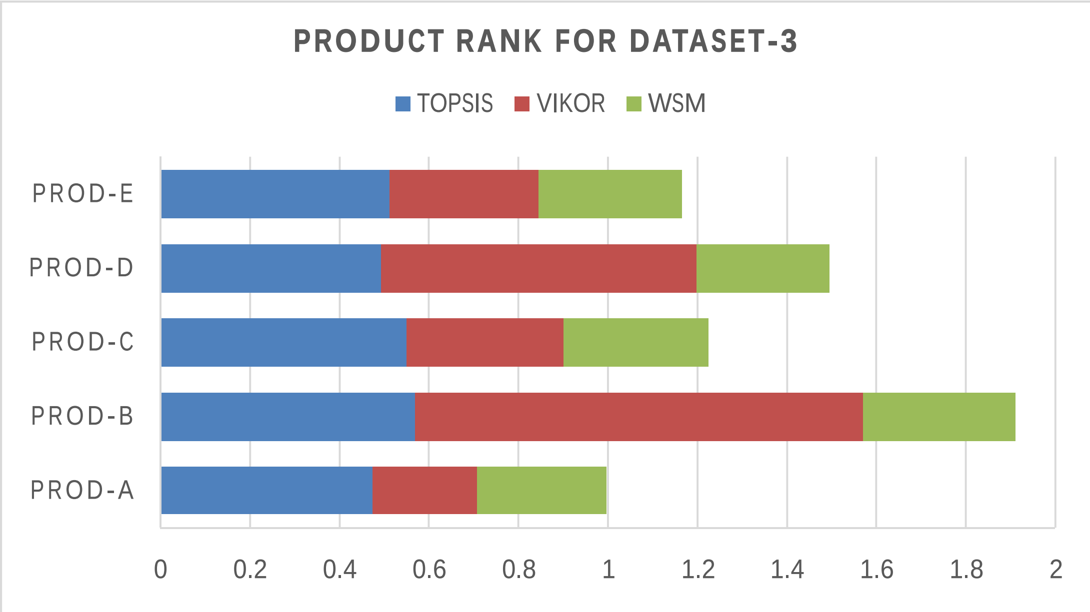

Figure 5: Ranking of alternatives from Dataset 3

Table 6 shows the rate of agreement in ranking order among the three MCDM models and Figure 6 graphically depicts this information. From the data we find that the rate of agreement among the models was 67% and the rate of disagreement was 33%.

Table 6: RATE OF AGREEMENT AMONG THE MODELS

	All Agree	Not Agree
Dataset-1	3	2
Dataset-2	5	0
Dataset-3	2	3
Totals	10	5
Percentage	67	33

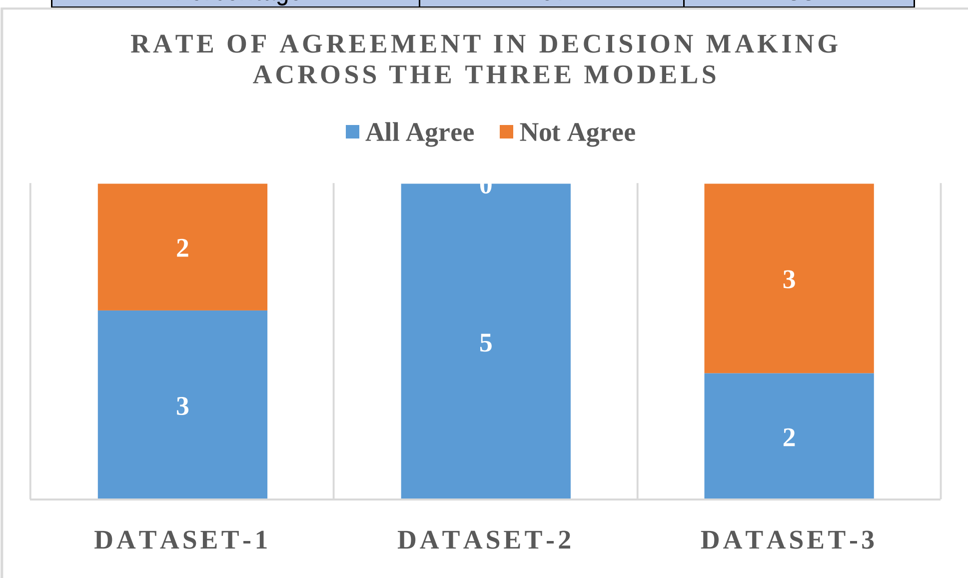

Figure 6: Rate of agreement/disagreement among TOPSIS, VIKOR and WSM rankings

VI. CONCLUSION AND RECOMMENDATION

The aim of the study was to compare the ranking schemes of three Multi Criteria Decision Making methods: WSM, TOPSIS and VIKOR to know if all three methods will propose the same software product for adoption with the same set of data and produce the same ranking schemes. The results show that the methods do not always produce the same ranking schemes.

Knowing the importance of choosing the right software product and the consequences of choosing the wrong one, more than one MCDM method should be applied to the software product evaluation data from decision makers, before the best alternative is recommended.

VII. FUTURE WORK

In the future, researchers can add other MCDM method to the three used in this research for comparison. Developing an improved ranking scheme that incorporates the results from this research will also be an interesting future direction.

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