Employing Multi-Attribute Decision Making Techniques To Pick A Two-Wheeled Scooter

Jaykirti Patil[1] and Ruturaj Sajane[2]

[1]Department of Mechanical Engineering, Walchand Institute of Technology, Solapur- 413006, India
[2]Department of Mechanical Engineering, Vishwakarma Institute of Technology, Pune- 411037, India

Abstract: **The two-wheeler market in India is divided into two parts, motorcycles and mopeds. There has been a vast increase in the demand for the two wheelers market. The evaluation of the bike selection is done on the basis of five major criteria such as cost, mileage, engine, fuel capacity and design. The present work relies on Analytical Hierarchy Process and VIseKriterijumska Optimizacija I Kompromisno Resenje technique for the choice of the best scooter in a very set of alternatives. It involves rating the criteria and aggregating them to find the most suitable alternatives are integrated. The weights of the standards are calculated followed by normalizing and prioritizing the alternatives of five types of scooters which are available within the market having price less than one lakh. The same weights are used to solve the VIKOR method. The result ranks Hero Pleasure Plus as the best motorcycle among other options.**

Keywords: Analytical Hierarchy Process, Bike selection, Multi-Attribute Decision Making method, Decision matrix, Normalized matrix, pairwise comparison.

Abbreviations	Name
AHP	Analytical hierarchy process
VIKOR	VIseKriterijumska Optimizacija I Kompromisno Resenje
SAW	Simple Additive Weighting
MOORA	Multi-Objective Optimization Method by Ratio Analysis
TOPSIS	Technique of Order Preference by Similarity to Ideal Solution
GM	Geometric Mean
MADM	Multi-Attribute Decision making

1. INTRODUCTION

India has a vast market for two-wheeler scooters, motorbikes and mopeds. These are considered the dominant transportation facilities in India. The young generation prefer two wheelers over four wheelers. Around one third part has been covered by the scooters in India. Due to the large volume market, many companies have launched different kinds of scooters according to the people's need and compatibility. The scooter companies keep on updating their designs every year with new designs, new features, latest models, etc. In recent years the market has been aggregated by the increasing purchase in the urban and rural areas. The factors that dominate during the purchase are fuel efficiency, low maintenance cost, low weight, comfortable to ride, etc. Some of the profit earning companies of two-wheeler in India are Hero, TVS, Yamaha, Suzuki.

Two-wheeler selection is a Multi-Attribute Decision Making method (MADM). The previous findings have shown that applications of the Simple Additive Weighting (SAW), Multi-Objective Optimization Method by Ratio Analysis (MOORA), Complex Proportional Assessment (COPRAS), Technique of Order Preference by Similarity to Ideal Solution (TOPSIS), Multi-Attribute Border Approximation Area Comparison (MABAC) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) algorithms are widely used in the choice-making procedure. Biswasa and Sahab [1] aimed at selecting commercially available scooters with the new Multi-Attribute Decision Making (MADM) method. The paper used the AHP and VIKOR method to determine process weight coefficients and then to select and test scooters available using the MADM method.

2. LITERATURE SURVEY

Many selection-making issues are solved by means of using the AHP method. Researchers have used this method for different topics but there is very little literature published on the selection of scooters. In this section we will go through the research studies based on the AHP method.

Gompf et al. [2] discussed using the AHP method to introduce weights in the public health cycle travel test. Experts of sustainable urban mobility were divided into three groups so as to research the similarities and differences between the groups. Issar [3] found and evaluated Iranian e-commerce websites by employing fuzzy AHP method. The factors affecting the success of these websites were discussed in the paper. Zuraidi et al. [4] applied AHP's approach to judging aspects and conditions of disability in heritage structures. The paper aimed to unravel the element type for building defects using AHP and create a strategic legacy building process in Malaysia. Hruška et al. [5] used AHP method for the choice of supplier. To increase the power inside the global market it's essential to be competitive and reply to the converting marketplace and therefore dealer selection is one most of the crucial features. Mardani et al. [6] discussed the various uses of the VIKOR method in regions along with sustainability and renewable electricity. The study discussed approximately 176 papers as well explored the status of Art Literature in terms of methods and techniques. Taiwan is ranked first among 22 nations using the VIKOR method. Haw Ho et al. [7] elaborated on an evaluation process to pick out barriers to the green and powerful use of electronics and electronics groups in the Malaysian context. Russoa and Camanhob [8] are presented with conditions in the AHP outlined in a systematic review of the literature. This paper explains how estimates are measured and defined.

Alkafas et al. [9] introduced the use of the intuitionistic fuzzy VIKOR as a solution to the problem of resource selection. Determination values are determined accurately. Decision matrix is vague and converted into obscure decision matrix. Pathinathan et al. [10] hired VIKOR to compile Pentagonal Fuzzy Numbers (PFN) in order to find a better solution to conflicting situations. Also found in the most suitable crop for planting using samples from 22 blocks from the Villupuram district. Lapevski and Timovski [11] presented on AHP Method used inside the manner of choice and followed by the assessment of the tender. It explained the importance of getting a tender for the organisation and how important it is to decide the criteria. Cetinkaya [12] discussed the Bike sharing station site selection for Gaziantep. The paper decides a location for bike sharing in Gaziantep. Hamed Taherdoost [13] presented a gradual method to the decision-making process using AHP. Yun Do and Kim [14] focused on the study of computable necessities within the choice model for restore material. It is categorized into two parts. AHP method was proposed to select a repair material. Luqman et al. [15] detailed the process of manufacturing the crank of composite bicycle by using AHP method to select the manufacturing process. Yadav and Gangele [16] presented a model of QFD (Quality Function Deployment), AHP and TOPSIS to study and executed it with two-wheeler selection in Indian markets. The work used QFD with AHP, TOPSIS. Kanjanakorn and Piantanakulchai [17] used AHP method to prioritize the selection of bike sharing stations. Zolfani et al. [18] studied and applied logarithmic normalization to the popular MADM methods VIKOR and TOPSIS. Ankit and Manoj [19] employed a method distinguished with app requirements, possibilities, virtual values, and preferences. AHP method was used for the choice of materials for the robot arm. Shahroodi and Kambiz [20] have proposed the AHP process to judge and choose distributors in an efficient supply network with the assistance of six criteria.

This paper is based on the AHP and VIKOR method application for the selection of the most preferred scooter from the alternatives. The paper follows through introductory part and literature survey. Further it presents the mathematical formulation of the technique followed by the basic steps of the method and the results. The weights are calculated using the AHP method. Five major criteria for the selection of a scooter are considered. The most popular scooters like Honda Activa 5G, Yamaha Fascino, TVS Jupiter, Suzuki Access 125, Hero Pleasure are selected as the alternatives.

3. METHODOLOGY

3.1 AHP Method

It is an advanced and straightforward tool for understanding touch to touch on complex, informal and multifaceted issues developed by T.L Saaty. It's one in all the foremost common analytical techniques for complicated higher cognitive process issues. The key procedure of AHP using the Geometric Mean (GM) method is as follows,

Step 1: Find out the target and analysis attributes. Assemble an information structure with a goal on the very excellent level, followed by the attributes and the options.

Step 2: Find the related magnitude of the various attributes by referring to the goal. Create an intelligent comparison matrix using a related value scale. The correlation in the nursing quote compared to it is usually given a value of 1, so the diagonal entries are the main matrix of intelligent comparisons in both. Taking up N attributes for the problem, the pair-wise comparison of attribute i with attribute j gives a BN x N matrix wherever, aij denotes the relative importance of attribute i with relevance attribute j. within the matrix, bij= 1 once i = j and bji. The average standard weight (wj) of each attribute is determined by setting the meaning of the ith line and by normalizing the values of the geometric definition of the lines within the comparison matrix.

Table 1. The fundamental scale for pair-wise comparisons

Intensity of importance	Verbal scale	Description
1	Equal importance	Two tasks are equally relevant to the purpose.
3	Moderate importance	The judgment somewhat favors one activity over another.
5	Strong importance	The judgment strongly favors one activity over another.
7	Very strong importance	An activity is strongly favored over another.
9	Absolute importance	It is the best possible order of assurance.
2,4,6,8	Intermediate values	Used to represent compromise between the priorities when needed.

Normal average weights are obtained using the AHP geometric method and thanks to its guidance and its ease of detecting eigen value and reducing solution inconsistencies.

$GM_j = [\Pi b_{ij}]^{1/N}$ … (A.1)

$W_j = GM / \Sigma\ GM_j$ … (A.2)

- Find out A3 and A4 matrices, stated A3 = A1 x A2 and A4=A3 /A2,
- Here, A2 = [w1, w2… wj] T and A1 = Decision matrix
- Compute the utmost eigen value λmax (average of A4).
- Compute the consistency index CI = (λmax - N)/ (N - 1). The smaller the CI value, the smaller the difference from the correlation and M indicates the size of the matrix.
- Get random index values (RI) for the variety of attributes employed in deciding.
- Find the corresponding rating, CR = CI / RI. Basically, a CR value of 0.1 or less than 0.1 is considered ideal because it reflects the informed judgment that can be attributed to the analyst's knowledge of the subject matter being studied.

Table 2. Values of Random Index

Attributes	3	4	5	6	7	8	9	10
RI	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

Step 3: An additional step is to wisely differentiate pairs when considering which is the best part for each merit advantage. If there are M number of choices, then there will be an N number of M x M for judicial decisions as there are N attributes. Using a related value scale, create clever comparison matrices. Use the basic scale of AHP to enter the judgements. The steps are similar to step 2.

Step 4: Create a matrix table for normalized pair wise comparison and their weights.

Step 5: Repeat the corresponding process by their weights to find the level of attributes. The result is a 4×1 matrix.

3.2 VIKOR Method

VIKOR was founded by Serafim Opricovic to solve problems of conflicting and different unit decisions. The VIKOR has following procedures: -

Step 1: To find out the target attributes. Compute the normalized decision matrix to assess the best and worst values among the attributes, where i=1,2, ..., m and j=1,2, ..., n. Also find out the beneficial and non- beneficial attributes.

$$f_{ij} = (I\_i^j)/\sqrt{(\Sigma\_{(i=1)}^m (I\_i^j)^2)}$$ … (B.1)

Step 2: Calculate Si and Ri values by expressing the relative importance of the criteria and take out maximum and minimum values of Si and Ri.

Beneficial attributes

$Si = \Sigma\_{(i=1)}^n \{W_i [((f_{ij})\_{max} - (f_{ij}))/ ((f_{ij})\_{max} - (f_{ij})\_{min})]\}$ …(B.2)

$Ri = max\ of\ [\![\{W_i [((f_{ij})\_{max} - (f_{ij}))/((f_{ij})\_{max} - (f_{ij})\_{min})]\}]\!]$ … (B.3)

Non - beneficial attributes

$Si = \Sigma\_{(i=1)}^n \{W_i [((f_{ij}) - (f_{ij})\_{min}/((f_{ij})\_{max} - (f_{ij})\_{min})]\}$ …(B.4)

$Ri = max\ of\ [\![\{W_i [((f_{ij}) - (f_{ij})\_{min}/((f_{ij})\_{max} - (f_{ij})\_{min})]\}]\!]$ … (B.5)

Step 3: This step describes the assessment of Qi for the group utility function. It signifies the VIKOR index. These strategies can be compromised by v, standard value of v=0.5, however the value ranges between 0 to 1.

$$Qi = v [(Si - (Si)\_{min}/((Si)\_{max} - (Si)\_{min})] + (1-v) [(Ri - (Ri)\_{min}/((Ri)\_{max} - (Ri)\_{min})]$$ … (B.6)

Step 4: Rank the choices in scaling order and find the best alternative.

Step 5: Confirmation of the rank choice. These comprises of two cases:

Case 1: Q(a2) - Q(a1) >= DQ, where DQ = 1/ (j-1), j = number of attributes, a1 is the top ranked alternative and a2 is the second ranked alternative.

Case 2: Choice of random acceptance stability, where Qi is the best choice from S and R with v >=5, that is, the alternatives must also be top ranked by the S and R values.

4. PROBLEM STATEMENT

In recent years, we see an increase in the sales of two wheelers. Today, we have a lot of choices to buy a new bike or scooter. The people will definitely choose the best scooter which has the best features and comfort. But people get confused while buying the scooter. Presently five popular scooters in India are Honda Activa 125, Yamaha Fascino, TVS Jupiter, Suzuki Access 125, Hero Pleasure. The attributes considered for comparing the scooters are Cost, Mileage, Engine, Fuel capacity, Design.

Table 3. Problem Statement

Serial no.	Bike name	Cost (Rs)	Mileage (km/l)	Engine (cc)	Fuel capacity (l)	Design
1	Honda Activa 125	74,107	60	124.0	5.3	Good
2	Yamaha Fascino	76,479	66	125.0	5.2	Excellent
3	TVS Jupiter	65,155	62	109.7	6	Good
4	Suzuki Access 125	73,933	64	124.0	6	Excellent
5	Hero Pleasure Plus	62,500	63	110.9	4.8	Good

5. SOLUTIONS BY USING THE SELECTED MADM METHODS

5.1 AHP Method

Step 1: The objective is to choose the best scooter from the options.

Step 2: Calculation of weights. The table shows the relative importance of each alternative with each other.

Table 4. Pair wise Decision matrix

	Cost	Mileage	Engine	Fuel capacity	Design
Cost	1	2	3	7	5
Mileage	0.5	1	4	7	6
Engine	0.33	0.25	1	4	3
Fuel capacity	0.14	0.14	0.25	1	0.33
Design	0.2	0.17	0.33	3	1

Geometric mean calculation and weight calculation by using the Eq (A.1) and Eq (A.2) respectively.

GM_1 = 2.9137; GM_2 = 2.4258; GM_3 = 0.9980; GM_4 = 0.2765; GM_1 = 0.5075;

W1 = 0.4091, W2 = 0.3406, W3 = 0.1401, W4 = 0.0388, W5 = 0.0713

Table 5. Values of A2, A3, A4 matrix

A2 (Weights)	A3 = A1*A2	A4 = A3/A2
0.4091	2.1389	5.2279
0.3406	1.8051	5.2994
0.1401	0.7294	5.2050
0.0388	0.2023	5.2111
0.0713	0.3737	5.2446

Now, Eigen's maximum value is calculated by taking the matrix A4 value i.e., Λmax = A4 / 5 = 5.2376

Calculating Consistency Index (CI) = (Λmax – M) / (M – 1) = (5.4253 – 5)/ (5 – 1) = 0.0594

Calculating Consistency Ratio (CR) = CI / RI = 0.0594 / 1.11 = 0.0535.

[The RI value is chosen from the table for the four choices] Since the CR < 0.1, therefore the weights are correct.

Step 3: Construct a Normalized Decision Matrix. Note down the values of weights in the table.

Table 6. Normalized Decision Matrix

	Cost	Mileage (km/l)	Engine (cc)	Fuel capacity (l)	Design	Weights
Honda Activa 125	0.8434	0.9091	0.9920	0.8833	0.8000	0.4091
Yamaha Fascino	0.8172	1.0000	1.0000	0.8667	1.0000	0.3406
TVS Jupiter	0.9593	0.9394	0.8776	1.0000	0.8000	0.1401
Suzuki Access 125	0.8454	0.9697	0.9920	1.0000	1.0000	0.0388
Hero Pleasure Plus	1.0000	0.9545	0.8872	0.8000	0.8000	0.0713

Step 4: Consider one alternative and multiply each attribute with their respective weights. Give the respective ranking to the scooter,

Table 7. Weighted Normalized Decision Matrix with Ranking

Attributes	Values	Rank
Honda Activa 125	0.8850	5
Yamaha Fascino	0.9200	4
TVS Jupiter	0.9312	2
Suzuki Access 125	0.9252	3
Hero Pleasure Plus	0.9466	1

5.2 VIKOR Method

Step 1: To find out the target attributes. Compute the normalized decision matrix to check the best and worst values between attributes, where i=1,2, ..., m and j=1,2, ..., n. Also find out the beneficial and non- beneficial attributes as present in table 8.

Table 8. Normalized decision matrix

Bike name	Cost (Rs)	Mileage (km/l)	Engine (cc)	Fuel capacity (l)	Design
Honda Activa 125	34762.43	25.54	57.82	2.29	1.62
Yamaha Fascino	37023.38	30.91	58.76	2.21	2.53
TVS Jupiter	26871.21	27.27	45.26	2.94	1.62
Suzuki Access 125	34599.38	29.06	57.82	2.94	2.53
Hero Pleasure Plus	24725.88	28.16	46.25	1.88	1.62
	NB	B	B	B	B
Best value ($(f_{ij})\_max$)	37023.38	30.91	58.76	2.94	2.53
Worst value ($(f_{ij})\_min$)	24725.88	25.54	45.26	1.88	1.62

Step 2: Calculate Si and Ri values by expressing the relative importance of the criteria and take out largest and smallest values from the summation of Si and Ri values as shown in the table below. Equation (B.2) and (B.4) are used to calculate the Si values, whereas equation (B.3) and (B.5) are used to calculate the Ri values.

Table 9. Calculation Si and Ri values

Bike name	Cost (Rs)	Mileage (km/l)	Engine (cc)	Fuel capacity (l)	Design	ΣSi	ΣRi
Honda Activa 125	0.08	0.00	0.00	0.08	0.00	0.7792	0.3406
Yamaha Fascino	0.00	0.13	0.01	0.02	0.00	0.4359	0.4091
TVS Jupiter	0.10	0.45	0.04	0.00	0.29	0.5134	0.2307
Suzuki Access 125	0.03	0.33	0.03	0.01	0.17	0.4553	0.3285
Hero Pleasure Plus	0.14	0.35	0.00	0.02	0.29	0.4142	0.1744

Step 3: This step describes the computation of Qi using equation (B.6) for the group utility function. It signifies the VIKOR index and is shown in table 10.

Table 10. Computation of Qi

Alternatives	Qi
Honda Activa 125	0.8541
Yamaha Fascino	0.5297
TVS Jupiter	0.2559
Suzuki Access 125	0.3845
Hero Pleasure Plus	0.0000

Step 4: Rank the alternatives in increasing order and find out the order preference as shown in table 11.

Table 11. Rank the alternatives

Alternatives	RANK
Honda Activa 125	5
Yamaha Fascino	4
TVS Jupiter	2
Suzuki Access 125	3
Hero Pleasure Plus	1

Step 5: Acceptance of the rank choice. It comprises two cases.
Case 1: Not satisfied because Q(a2) - Q(a1) is less than DQ.
Case 2: Case 2 is satisfied because some are better measured by the values of S and R. Considering the values in ascending order the first rank is best matched with the R value in the first row and the last rank matches with the S value in the third row shown in the table.

6. RESULTS AND DISCUSSION

From the above solution strategies, ranking of the selected attributes is done. The solution strategies of these two methods give the same ranking. The solution says that Hero Pleasure Plus has the highest rank among all and turns out to be the best bike considering all the criteria. It is affordable with a good mileage range and looks. It does have a good engine and fuel capacity. Followed by the TVS Jupiter comes the Suzuki Access 125, Yamaha Fascino. The Honda Activa 125 has the fifth rank among all the scooters which says that it has less value compared to other scooters in that price range. This is because the Activa has a high price and less mileage than the other scooters. Following table displays the ranks obtained by the two MADM methods.

Table12. Rankings with Respective methods

	AHP	VIKOR
Honda Activa 125	5	5
Yamaha Fascino	4	4
TVS Jupiter	2	2
Suzuki Access 125	3	3
Hero Pleasure Plus	1	1

7. CONCLUSION

Many researchers have used different MADM methods in various different applications and solved the decision-making problems using mathematical formulation. This paper aimed to select the best scooter from the alternatives and also focused on the attributes prioritized while selecting a scooter. Turns out that Hero Pleasure Plus is the best scooter among the alternatives offering good mileage and engine at a cheaper cost than the other alternatives. MADM method helps the people to rank the alternative scooters based on their subjective judgements concerning the value of attributes. The selected methods are easy to use and understand. The methods have wide flexibility in different industrial and domestic applications.

REFERENCES

[1] Biswasa T and Sahab P, (2019), Selection of commercially available scooters by new MCDM method, International Journal of Data and Network Science 3: (137–144)

[2] Gompf K, Traverso M, and Hetterich J, (2021), Using Analytical Hierarchy Process (AHP) to Introduce Weights to Social Life Cycle Assessment of Mobility Services', Sustainability ,13: (1-10)

[3] Issar A, (2008), Exploring and evaluating factors affecting success of Iranian e-commerce web sites using fuzzy analytic hierarchy process, Master's Thesis, 10(22)

[4] Zuraidi F, Rahman AA, Akasah ZA,(2018), A Study of using AHP Method to Evaluate the Criteria and Attribute of Defects in Heritage Building, E3S Web of Conferences 65, 01002

[5] Hruška R, Průša P,Babić D, (2014), The Use Of Ahp Method For Selection Of Supplier, Published by Researchgate (Transport), 29(2): (195–203)

[6] Abba.M ,Edmundas.K , Kannan.G, Aslan.A.S and Ahmad.J (2016). VIKOR Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications. International Journal of Applied Engineering Research, Vol.39, pp.S43-S55.

[7] Ho FH, Abdul-Rashid SH and Ghazilla RA ,(2014), Analytic Hierarchy Process-Based Analysis to Determine the Barriers to Implementing a Material Efficiency Strategy: Electrical and Electronics Companies in the Malaysian Context, Published by Sustainability Transport, 29(2): (195–203)

[8] Russo R, Camanho R, (2015), Criteria in AHP: a Systematic Review of Literature, Information Technology and Quantitative Management, Procedia Computer Science, 55: (1123 – 1132)

[9] S.S. Alkaffas, M. Fattouh, R. Masoud and O. Nada (2020). Intuitionistic Fuzzy VIKOR Method for Facility Location Selection Problem. International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol.10, pp.150.

[10] Pathinathan. T, Johnson Savarimuthu. and Mike Dison(2017). Extended VIKOR Method and its Application to Farming using Pentagonal Fuzzy Numbers. Global Journal of Pure and Applied Mathematics.ISSN 0973-1768 Vol.13, No 9, pp. 6801-6826.

[11] Atanasova–Pachemska T, Lapevski M, Timovski R,(2014), Analytical Hierarchical Process (Ahp) Method Application In The Process Of Selection And Evaluation, International Scientific Conference, (II 373-380)

[12] Çetinkaya C, (2017), Bike Sharing Station Site Selection For Gaziantep, Sigma Journal of Engineering and Natural Sciences, 35 (3): (535-543)

[13] Taherdoost H ,(2017), Decision Making Using the Analytic Hierarchy Process (AHP); A Step by Step Approach, International Journal of Economics and Management Systems, 2: (244-246)

[14] Do JY, and Kim DK, (2012), AHP-Based Evaluation Model for Optimal Selection Process of Patching Materials for Concrete Repair: Focused on Quantitative Requirement, International Journal of Concrete Structures and Materials, 6(2): (87–100)

[15] M. Luqman, M.U. Rosli, C.Y. Khor, Shayfull Zambree, H. Jahidi, (2018), Manufacturing Process Selection of Composite Bicycle's Crank Arm using Analytical Hierarchy Process (AHP), IOP Conf. Series: Materials Science and Engineering 318: (1-8)

[16] Yadav JS, (2017), Optimization of Selection Parameters through QFD-AHP-TOPSIS Methodology, International Journal of Theoretical and Applied Mechanics, 12(4): (833-844)

[17] Kanjanakorn T, Piantanakulchai M, (2013), Prioritizing Suitable Locations Of Bike Sharing Station By Using The Analytic Hierarchy Process (AHP), Proceedings of the International Symposium on the Analytic Hierarchy Process, (1-10)

[18] Sarfaraz Z, Morteza Y, Dragan P and Pascale Z (). A VIKOR AND TOPSIS focused reanalysis of the madm methods based on logarithmic normalization. facta universitatis Series: Mechanical Engineering, University of NIS. Vol.2, No.1-2, pp.27–35.

[19] Kumar A and Kumar M, (2019), Implementation of Analytic Hierarchy Process (AHP) as a Decision-Making Tool for Selection of Materials for the Robot Arm, International Journal of Applied Engineering Research, 14(11): (2727-2733)

[20] Shahroodi, Kambiz, (2012), Application of Analytical Hierarchy Process (AHP) Technique To Evaluate and Selecting Suppliers in an Effective Supply Chain, Kuwait Chapter of Arabian Journal of Business and Management 1(8): (1-14)