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Optimizing the Selection of Electric Bicycles Using a Combination of the MOORA Method and Entropy Weighting

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***Abstract*— *The increasing interest in electric bicycles among teenagers reflects an emerging trend in urban transportation. This research proposes an approach that combines the Multi-Objective Optimization by Ratio Analysis (MOORA) method with entropy weighting to choose an electric bicycle based on various criteria, responding to the needs and preferences of teenagers who increasingly pay attention to environmental aspects in selecting a mode of transportation. This method provides an effective framework for designing adaptive weighting systems, ensuring that each factor gets a proportional contribution according to its level of relevance in multi-criteria decision-making. These important steps in the process result in a ranking of electric bike alternatives based on net score, with the Commuter Electric Bike dominating as the best choice with the highest MOORA score. This research makes an important contribution to the understanding of how electric bicycles can be an effective solution in reducing environmental impact and traffic congestion, especially with their integration into bike-sharing programs in cities around the world.*

***Keywords*— *Electric bicycles, Multi-Objective Optimization by Ratio Analysis (MOORA), Teenagers, Urban transportation.*

I. INTRODUCTION

Electric bicycles are increasingly popular among teenagers due to their increased mobility, comfort, speed, and ability to provide electric assistance while riding, making the ride smoother and less noisy compared to traditional bicycles[1][2]. This feature not only improves the riding experience but also contributes to reducing air and noise pollution, making e-bikes an environmentally friendly transportation option[3][4]. This shows that electric bicycles not only provide direct benefits to users but also have a positive impact on the surrounding environment, creating an efficient and sustainable transportation solution for teenagers who are increasingly paying attention to environmental aspects in choosing modes of transportation[5][6][7].

To meet the needs and preferences of teenagers, especially those aged between 10 and 17 years and interested in using electric bicycles for daily activities such as going to school, various types of electric bicycles are available on the market[8][9]. These electric bikes come in various styles and serve unique purposes, each offering different features that fit certain criteria such as range, maximum speed, battery capacity, charging time, weight, riding comfort, safety, design and construction, durability, component quality, and price[10][11][12]. Choices for electric bicycles that are suitable for teenagers include Electric Folding Bicycles, Commuter Electric Bicycles, Electric Mountain Bikes, Hybrid Electric Bicycles, Urban Electric Bicycles, and Mini Electric Bicycles. This shows that electric bicycles not only efficiently meet the mobility needs of teenagers, but also provide a variety of options to suit their preferences and needs in using environmentally friendly transportation[13][14][15].

The four main components of an electric bicycle, namely the battery, electric motor, frame with gears and bicycle chain, and bicycle brakes, offer several advantages[16]. Electric bicycles can reduce the fatigue associated with using traditional bicycles, make traveling on hilly terrain easier, and enable long-distance travel at higher speeds[17][18]. Additionally, electric bicycles can overcome physical obstacles and are used easily by physically challenged individuals, making them a suitable option for teens with a variety of needs. The contribution of electric bicycles to environmental conservation and reducing traffic congestion has been proven. The integration of electric bicycles in bike-sharing programs in cities around the world shows the potential to transform urban transportation systems[19][20]. Although electric bicycles offer a cost-effective and environmentally friendly mode of transportation, new challenges are emerging related to safety and injury prevention. Some unlawful cycling practices, such as using excessive speed, and running red lights, can cause dental and maxillofacial injuries[9][21]. Therefore, it is important to take injury prevention measures and implement educational initiatives to ensure the safe use of e-bikes[22][23].

To help users choose the best electric bicycle based on the desired criteria, the Multi-Objective Optimization by Ratio Analysis (MOORA) method can be used. This decision-making method evaluates and continuously assesses various alternatives to help the decision-making process effectively[1][24]. By applying the MOORA method, users can compare various electric bicycle models based on certain criteria[23][25][26]. Research has shown that e-bikes play an important role in encouraging sustainable mobility and increasing the use of cycling among other modes of travel, contributing to environmental conservation and reducing traffic congestion[27]. Additionally, e-bikes have been integrated into bike-sharing programs in various cities around the world, demonstrating their potential to transform urban transportation systems and attract users to both regular and e-bikes, thereby

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expanding user mobility. The entropy weighting method provides an effective framework for designing adaptive weighting systems, ensuring that in multi-criteria decision-making, each factor gets a proportional contribution according to its level of relevance.

II. Methodology

The Multi-Objective Optimization by Ratio Analysis (MOORA) method combined with entropy weighting provides a comprehensive approach to selecting electric bicycles based on various criteria[28][1][26][29]. This process involves several important steps, which ultimately result in a ranking of electric bicycle alternatives based on net score. The research stages carried out are presented in Figure 1.

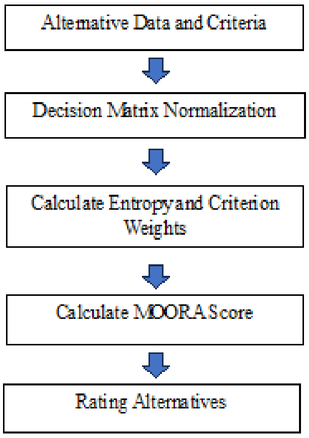

Fig. 1. Research Chart

A. Identify Criteria and Alternatives

The initial step in decision-making involves entering criteria values and setting goals to identify the evaluation attributes of each alternative[28][27]. These values are processed until a final decision. These values will then be processed to produce a final decision. The first stage is creating a decision matrix.

$$X = \begin{bmatrix} X_{11} & X_{21} & \cdots & X_{m1} \\ X_{12} & X_{22} & & X_{m2} \\ \vdots & & \ddots & \vdots \\ X_{1n} & X_{2n} & \cdots & X_{mn} \end{bmatrix}$$

Data is collected for each criterion and alternative in selecting an electric bicycle. This data is then processed to assess the criteria for each alternative[30]. The data collection process was carried out through surveys or interviews with 100 random teenagers to identify criteria and alternatives for electric bicycles. The entropy weighting method is used to determine the weight of criteria in a multi-criteria decision system.

B. Decision Matrix Normalization

By applying min-max vector normalization to all criteria and alternatives, the normalized value of each criterion for each alternative is calculated. This normalization process ensures that comparisons between criteria are carried out in a proportional and balanced manner. Data normalization with weights takes into account the proportional importance of each criterion in multi-criteria decision-making

$$x'_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \quad (1)$$

Utilization of data normalization methods, such as vector normalization, significantly improves the decision-making process by ensuring fair and standardized comparisons between criteria and alternatives objectivity and reliability of the multi-criteria decision-making process by establishing a common basis for evaluating different criteria[31][32].

C. Calculate Entropy and Criteria Weights

Entropy weighting is used to determine the weight of criteria in multi-criteria decision-making by taking into account the level of uncertainty or diversity of information on each criterion. The goal is to provide balanced weighting based on relative information contribution. This method supports more objective and informed decision-making by considering the uncertainty and diversity of information on each criterion[33][31].

Entropy is used to determine criteria weights based on the level of uncertainty and variation in the data. This weighting gives different emphasis to each criterion according to its importance:

1. Calculate the proportion of each alternative for each criterion.

   $$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (2)$$

   p_{ij} is a proposition of value x_{ij} to the total x_{ij} for all alternatives
2. Calculate the entropy ej for each criterion.

   $$ej = -k \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \quad (3)$$

   $k = \frac{1}{\ln(n)}$ and n is the number of alternatives.

   e_j is the entropy of the criterion

   j, k is a constant (in this case, $k = \frac{1}{\ln(n)}$), and n is the alternate number.
3. Calculate the Weight of the Criteria w_j

   $$w_j = \frac{1 - e_j}{m - \sum_{j=1}^{m} e_j} \quad (4)$$

   w_j is the weight of the criteria and is the sum of the criteria jm.

D. Score MOORA

1. Multiply the normalized value by the weight

The normalized data is then multiplied by the weight obtained from the entropy method to take into account the influence of each criterion proportionally.

$$y''_{ij} = w_j \cdot r'_{ij} \quad (5)$$

r'_{ij} is a previously normalized value.

The entropy method in calculating criteria weights after normalization provides a strong basis for adjusting the influence of criteria according to the level of uncertainty and variation. This allows proportional emphasis on each criterion, ensuring that uncertainties in the data are accounted for fairly in decision-making[34].

2. Calculate the MOORA score value

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The MOORA method helps in ranking alternatives by considering benefits and costs. By subtracting the value of the cost criterion from the value of the benefit criterion, this method provides a more holistic assessment of the performance of each alternative.

$$MOORA = \sum(Benefit) - \sum(cost) \quad (6)$$

$$y_i = \sum_{j \in B} w_j x_{ij}^{"} \quad (7)$$

y_i is the MOORA value for each alternatef i, Benefit is the set of criteria that are considered beneficial, and Cost is a set of criteria that are considered detrimental.

The MOORA value is calculated for each alternative by subtracting the number of normalized values for the cost criteria from the number of normalized values for the benefit criteria. Alternatives are then ranked based on the net score value.

III. Results And Discussin

A. Identify Criteria and Alternatives

Electric bicycle alternative:

1. Electric Folding Bike (A1): Suitable for daily use in the city with a range of 53 km, a maximum speed of 25 km/h, and a battery capacity of 400 Wh. With a battery charging time of 4 hours, a weight of 15 kg, and a price of 750 USD.
2. Commuter Electric Bike (A2): Ideal for fast travel with a range of 62 km, a maximum speed of 30 km/h, and battery capacity of 450 Wh. With a battery charging time of 4.1 hours, a weight of 20 kg, and a price of 900 USD.
3. Electric Mountain Bike (A3): Suitable for challenging terrain with a range of 70 km, a maximum speed of 31 km/h, and a battery capacity of 510 Wh. With a battery charging time of 65 hours, a weight of 23 kg, and a price of 825 USD.
4. Hybrid Electric Bike (A4): Very good for medium-distance travel with a range of 65 km, maximum speed of 27 km/h, and battery capacity of 470 Wh. With a battery charging time of 4 hours, a weight of 20 kg, and a price of 900 USD.
5. Urban Electric Bike (A5): Suitable for city use with a range of 62 km, a maximum speed of 25 km/h, and a battery capacity of 470 Wh. With a battery charging time of 4 hours, a weight of 20 kg, and a price of 800 USD.
6. Mini Electric Bike (A6): Distance 51 km, maximum speed 20 km/h. 380 Wh battery, 4 hours charging. Weight 18 kg. Price 620 USD

Criteria:

1. Range (K1): The distance an electric bicycle can travel on one battery charge, adjusted to the user's daily needs.
2. Max Speed (K2): The maximum speed an electric bicycle can reach, is important for safety and compliance with traffic regulations.
3. Battery Capacity (K3): Battery capacity, measured in watt-hours (Wh), affects mileage.
4. Charging Time (K4): The time to fully charge the battery, the shorter the more practical.
5. Weight (K5): The total weight of the bicycle, including the battery, affects agility and ease of use.
6. Comfort (K6): Comfort factors such as suspension and ergonomic saddle design.
7. Safety (K7): Safety features such as disc brakes and lights are important for driver protection.
8. Durability (K8): Durable quality of the frame and materials, also considering aesthetics.
9. Component Quality (K9): Quality of motor, battery, and other components for long-term reliability.
10. Price (K10): The price of an electric bicycle is balanced with the features offered, providing the best value for users

Collect data for each criterion from various alternatives.
The assessment data for each alternative is presented in table 1 as follows:

TABLE 1. Criteria and Alternatives

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
A1	53	25	400	4	15	7	9	7	7	750
A2	62	30	450	4.1	20	8	7	8	9	900
A3	70	31	510	5	23	7	9	9	10	825
A4	65	27	470	4	21	7	8	10	9	900
A5	62	25	420	4	20	8	7	7	8	800
A6	51	20	380	4	18	7	8	6	7	620

B. Decision Matrix Normalization

Normalization of the decision matrix is carried out to ensure that all criteria can be compared directly. The value of each criterion is normalized using the vector method to ensure the values are on the same scale. using equation (2)

TABLE 2. Decision Matrix Normalization

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
A1	0.3	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3
A2	0.4	0.5	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.4
A3	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4
A4	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4
A5	0.4	0.4	0.3	0.3	0.3	0.4	0.3	0.4	0.4	0.3
A6	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

a. Electric Folding Bike has high normalized values for Comfort (0.3) and Safety (0.4), but lower for Battery Capacity (0.3) and Weight (0.3).
b. Commuter Electric Bike stands out in Comfort (0.4), Component Quality (0.4), and Price (0.5), but weak in Charging Time (0.3).
c. The Electric Mountain Bike recorded the highest scores in Range (0.5), Battery Capacity (0.4), Durability (0.6), and Component Quality (0.5), as well as high marks for Price (0.6).
d. The Hybrid Electric Bike has high scores for Comfort (0.4) and Component Quality (0.4), with consistent performance across a wide range of criteria.
e. The Urban Electric Bike stands out in Comfort (0.5) and has a reasonable price (0.4), but scores low for Battery Capacity (0.4) and Weight (0.3).
f. The Mini Electric Bike scores low for most criteria, especially in Range (0.3) and Battery Capacity (0.3), but relatively high for Comfort (0.4) and Safety (0.3).

C. Calculate Entropy and Criteria Weights

Entropy measures the uncertainty in the data for each criterion, while weights are calculated based on the entropy value to determine the importance of each criterion. This calculation uses equation (3) to calculate Propability p_ij, and

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equation (4) to calculate Entropy e_j, then calculate w_j with equation (5). From the calculations equations (3,4,5)

TABLE 3. Value Proportion Analysis

Alternative	Proportion
Electric Folding Bike	[0.163, 0.167, 0.152, 0.167, 0.161, 0.19],
Commuter Electric Bike	[0.195, 0.2, 0.182, 0.2, 0.194, 0.229],
Electric Mountain Bike	[0.217, 0.194, 0.214, 0.186, 0.197, 0.197],
Hybrid Electric Bike	[0.188, 0.176, 0.187, 0.179, 0.189, 0.216],
Urban Electric Bike	[0.170, 0.182, 0.161, 0.174, 0.183, 0.221],
Mini Electric Bike	[0.067, 0.051, 0.104, 0.095, 0.076, 0.133]

In the value proposition analysis, the Electric Folding Bike stands out in comfort (0.19) and maximum speed (0.167), while the Electric Mountain Bike is dominated by mileage (0.217) and battery capacity (0.214). The Hybrid Electric Bike stands out for price (0.216) and mileage (0.188), while the Urban Electric Bike highlights for price (0.221) and comfort (0.183). The Mini Electric Bike stands out in battery capacity (0.104) and charging time (0.095).

TABLE 4. Analysis of Entropy values

Alternative	Entropy
Electric Folding Bike	[1.791, 1.778, 1.801, 1.779, 1.784, 1.75],
Commuter Electric Bike	[1.773, 1.766, 1.781, 1.766, 1.77, 1.753],
Electric Mountain Bike	[1.756, 1.784, 1.758, 1.788, 1.779, 1.779],
Hybrid Electric Bike	[1.774, 1.795, 1.774, 1.792, 1.772, 1.754],
Urban Electric Bike	[1.784, 1.776, 1.791, 1.782, 1.775, 1.751],
Mini Electric Bike	[1.882, 1.926, 1.831, 1.856, 1.894, 1.761]

Entropy analysis shows variations in the level of uncertainty in assessing value proportions for each criterion for each alternative. The range of entropy values for each type of bicycle is as follows: Electric Folding Bike (1.75-1.801), Commuter Electric Bike (1.753-1.781), Electric Mountain Bike (1.756-1.788), Hybrid Electric Bike (1.754-1.795), Urban Electric Bike (1,751-1,791), and Mini Electric Bike (1,761-1,926). This indicates different levels of uncertainty in the assessment of the value propositions between the alternatives.

TABLE 5. Value Weight analysis

Alternative	Weight
Electric Folding Bike	[0.209, 0.222, 0.199, 0.221, 0.216, 0.25],
Commuter Electric Bike	[0.227, 0.234, 0.219, 0.234, 0.23, 0.247],
Electric Mountain Bike	[0.244, 0.216, 0.242, 0.212, 0.221, 0.221],
Hybrid Electric Bike	[0.226, 0.205, 0.226, 0.208, 0.228, 0.246],
Urban Electric Bike	[0.216, 0.224, 0.209, 0.218, 0.225, 0.249],
Mini Electric Bike	[0.118, 0.074, 0.169, 0.144, 0.106, 0.239]]

The Electric Folding Bike has the highest weight in Maximum Speed (0.222) and Durability (0.25), showing the great influence of these two criteria on the performance of the Electric Folding Bike. The Commuter Electric Bike has the highest weighting in Charging Time (0.234) and Price (0.247), showing superiority in both aspects compared to other alternatives. The Mini Electric Bike has the lowest weight in Comfort (0.106) and Safety (0.144), indicating that the Mini Electric Bike is less suitable for uses that emphasize comfort and safety. The Electric Mountain Bike has an even weight in all criteria, showing a good balance in the aspects assessed.

D. Skor MOORA

Calculation of the MOORA value begins by determining the criteria weights using the entropy method. The data is then normalized by multiplying each value by the predetermined criteria weight. Next, the MOORA value is calculated by subtracting the total normalized value for cost criteria from the total normalized value for benefit criteria. The results can be seen in Table 6.

TABLE 6. Analysis of MOORA Score calculations

Alternative	Benefit Score	Cost Score	MOORA Score
Electric Folding Bike	0.343	0.256	0.087
Commuter Electric Bike	0.389	0.287	0.102
Electric Mountain Bike	0.435	0.339	0.096
Hybrid Electric Bike	0.385	0.286	0.099
Urban Electric Bike	0.366	0.275	0.091
Mini Electric Bike	0.315	0.239	0.076

Based on analysis using the Multi-Objective Optimization by Ratio Analysis (MOORA) method, the Commuter Electric Bike shows the best performance with the highest MOORA score (0.102), even though it has a relatively high cost score (0.287), due to a greater benefit score (0.389). Electric Mountain Bike ranked second with a MOORA score of 0.096, where the highest benefit score (0.435) was offset by its high cost (0.339). The Hybrid Electric Bike ranked third with a MOORA score of 0.099, indicating a good balance between benefits (0.385) and costs (0.286). Urban Electric Bike is in fourth place with a MOORA score of 0.091, followed by Electric Folding Bike in fifth place with a MOORA score of 0.087. The Mini Electric Bike ranks last with the lowest MOORA score (0.076), due to the lowest benefit and cost scores (0.315 and 0.239).

E. Ranking Level

Alternative Ranking, the final stage is to rank alternatives based on alternative optimization values, ranking results as in table 7.

TABLE 7. MOORA Score ranking levels

Rating	Alternative	MOORA Score
1	Commuter Electric Bike	0.102
2	Hybrid Electric Bike	0.099
3	Electric Mountain Bike	0.096
4	Urban Electric Bike	0.091
5	Electric Folding Bike	0.087
6	Mini Electric Bike	0.076

Commuter Electric Bike is the best choice with the highest MOORA score of 0.102. This shows that this bicycle provides the best combination of benefits obtained and costs incurred.

Hybrid Electric Bike is in second place with a MOORA score of 0.099. While slightly inferior to the Commuter Electric Bike, this bike still offers excellent value.

Electric Mountain Bike is in third place with a MOORA score of 0.096. This bike also offers good value, but slightly less than the Hybrid Electric Bike.

Urban Electric Bike is in fourth place with a MOORA score of 0.091. While still in a good category, this bike offers less value than the three alternatives above it.

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Electric Folding Bike is in fifth position with a MOORA score of 0.087. This bike has a lower value than the Urban Electric Bike, but is still an option worth considering.

Mini Electric Bike is in last place with the lowest MOORA score of 0.076. This shows that this bike offers the lowest overall value after taking into account its benefits and costs.

IV. Conclusion

Combining the MOORA method with entropy weighting is a comprehensive approach to multi-criteria decision making. MOORA provides a framework for assessing alternatives based on the ratio of positive and negative ideal solutions, while entropy weighting contributes by taking into account the level of uncertainty in each criterion. Based on the combination of the Entropy and MOORA methods, the Commuter Electric Bike is the best and safest choice for use by teenagers for transportation to school. With the highest MOORA score of 0.102, this bike offers an optimal combination of benefits provided and costs incurred. In addition, taking into account the relatively low Entropy value in the criteria of safety, comfort and speed, the Commuter Electric Bike has attributes that are suitable and safe for use by teenagers on their daily trip to school.

References

[1] C. Te Lin, J. J. Yang, W. J. Chiang, J. J. Yang, and C. C. Yang, "Analysis of Mutual Influence Relationships of Purchase Intention Factors of Electric Bicycles: Application of DEMATEL Taking into Account Information Uncertainty and Expert Confidence," *Complexity*, vol. 2022, 2022, doi: 10.1155/2022/3444856.

[2] R. Cordovil *et al.*, "Learning to Cycle: A Cross-Cultural and Cross-Generational Comparison," *Front. Public Heal.*, vol. 10, no. April, 2022, doi: 10.3389/fpubh.2022.861390.

[3] C. Koop, J. Grosse Erdmann, J. Koller, and F. Döpper, "Circular Business Models for Remanufacturing in the Electric Bicycle Industry," *Front. Sustain.*, vol. 2, no. December, pp. 1–16, 2021, doi: 10.3389/frsus.2021.785036.

[4] T. Zhu, Z. Zhu, J. Zhang, and C. Yang, "Electric bicyclist injury severity during peak traffic periods: A random-parameters approach with heterogeneity in means and variances," *Int. J. Environ. Res. Public Health*, vol. 18, no. 21, 2021, doi: 10.3390/ijerph182111131.

[5] T. Berk *et al.*, "Increased injury severity and hospitalization rates following crashes with e-bikes versus conventional bicycles: an observational cohort study from a regional level II trauma center in Switzerland," *Patient Saf. Surg.*, vol. 16, no. 1, pp. 1–6, 2022, doi: 10.1186/s13037-022-00318-9.

[6] V. Gitelman, A. Korchatov, and W. Elias, "Speeds of Young E-Cyclists on Urban Streets and Related Risk Factors: An Observational Study in Israel," *Safety*, vol. 6, no. 2, 2020, doi: 10.3390/safety6020029.

[7] J. Li, J. Shen, and B. Jia, "Exploring intention to use shared electric bicycles by the extended theory of planned behavior," *Sustain.*, vol. 13, no. 8, 2021, doi: 10.3390/su13084137.

[8] S. L. Handy and D. T. Fitch, "Can an e-bike share system increase awareness and consideration of e-bikes as a commute mode? Results from a natural experiment," *Int. J. Sustain. Transp.*, vol. 16, no. 1, pp. 34–44, 2022, doi: 10.1080/15568318.2020.1847370.

[9] L. Stilo, H. Lugo, D. S. Velandia, P. P. Conway, and A. A. West, "Personalised Controller Strategies for Next Generation Intelligent Adaptive Electric Bicycles," *IEEE Trans. Intell. Transp. Syst.*, vol. 22, no. 12, pp. 7814–7825, 2021, doi: 10.1109/TITS.2020.3009400.

[10] J. E. Bourne *et al.*, "The impact of e-cycling on travel behaviour: A scoping review," *J. Transp. Heal.*, vol. 19, no. August, p. 100910, 2020, doi: 10.1016/j.jth.2020.100910.

[11] C. R. Cherry, J. X. Weinert, and Y. Xinmiao, "Comparative environmental impacts of electric bikes in China," *Transp. Res. Part D Transp. Environ.*, vol. 14, no. 5, pp. 281–290, 2009, doi: 10.1016/j.trd.2008.11.003.

[12] W. Kontar, S. Ahn, and A. Hicks, "Electric bicycles sharing: opportunities and environmental impacts," *Environ. Res. Infrastruct. Sustain.*, vol. 2, no. 3, 2022, doi: 10.1088/2634-4505/ac7c8b.

[13] M. Fahrizal, J. M. Diah, and D. Herdiansyah, "The use of digital content in increasing consumer awareness and interest towards electric bicycles," *Int. J. business, Econ. Manag.*, vol. 7, no. 1, pp. 27–34, 2024, doi: 10.21744/ijbem.v7n1.2250.

[14] S. Phadte, S. Shenvi, S. Prabhudesai, and J. Sawant, "Electrically Assisted Bicycle Adapted to Urban Mobility," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 10, no. 8, pp. 423–426, 2022, doi: 10.22214/ijraset.2022.46205.

[15] N. Of, "N Onlinear a Nalysis of P Ower a Mplifiers," *Microw. J.*, vol. 831, no. September, pp. 831–838, 2007.

[16] G. Ekanayake, M. Suresh Patil, J. H. Seo, and M. Y. Lee, "Numerical study on heat transfer characteristics of the 36V electronic control unit system for an electric bicycle," *Energies*, vol. 11, no. 10, 2018, doi: 10.3390/en11102506.

[17] D. Higuera-Mendieta, P. A. Uriza, S. A. Cabrales, A. L. Medaglia, L. A. Guzman, and O. L. Sarmiento, "Is the built-environment at origin, on route, and at destination associated with bicycle commuting? A gender-informed approach," *J. Transp. Geogr.*, vol. 94, no. November 2020, 2021, doi: 10.1016/j.jtrangeo.2021.103120.

[18] *et al.*, "Multi-Criteria Decision-Making for Electric Bicycle Selection," *Adv. Eng. Lett.*, vol. 1, no. 4, pp. 126–135, 2022, doi: 10.46793/adeletters.2022.1.4.2.

[19] P. Di Giorgio, G. Di Ilio, G. Scarpati, G. Erme, E. Simeoni, and E. Jannelli, "Design of a hydrogen-powered bicycle for sustainable mobility," *E3S Web Conf.*, vol. 334, pp. 1–6, 2022, doi: 10.1051/e3sconf/202233406012.

[20] C. Hall *et al.*, "Pedal-assist mountain bikes: A pilot study comparison of the exercise response, perceptions, and beliefs of experienced mountain bikers," *JMIR Form. Res.*, vol. 3, no. 3, pp. 1–11, 2019, doi: 10.2196/13643.

[21] S. Melo and P. Baptista, "Evaluating the impacts of using cargo cycles on urban logistics: integrating traffic, environmental and operational boundaries," *Eur. Transp. Res. Rev.*, vol. 9, no. 2, 2017, doi: 10.1007/s12544-017-0246-8.

[22] E. Papaioannou, C. Iliopoulou, and K. Kepaptsoglou, "Last-Mile Logistics Network Design under E-Cargo Bikes," *Futur. Transp.*, vol. 3, no. 2, pp. 403–416, 2023, doi: 10.3390/futuretransp3020024.

[23] J. Guanetti, S. Formentin, M. Corno, and S. M. Savaresi, "Optimal energy management in series hybrid electric bicycles," *Automatica*, vol. 81, pp. 96–106, 2017, doi: 10.1016/j.automatica.2017.03.021.

[24] I. Cahyadi, T. Novianti, E. Widiaswanti, H. A. Ilhamsah, S. Purwoko, and A. S. Hidayat, "Sea Cucumber Suppliers Selection Using Multi – Objective Optimization on The Basis of Ratio Analysis Methods," *MATEC Web Conf.*, vol. 372, p. 02004, 2022, doi: 10.1051/matecconf/202237202004.

[25] D. Zhou *et al.*, "Analysis of Risky Driving Behavior of Urban Electric Bicycle Drivers for Improving Safety," *Sustain.*, vol. 14, no. 3, pp. 1–19, 2022, doi: 10.3390/su14031243.

[26] X. Ding and J. Zhong, "Power Battery Recycling Mode Selection Using an Extended MULTIMOORA Method," *Sci. Program.*, vol. 2018, 2018, doi: 10.1155/2018/7675094.

[27] V. M. M. Siregar, M. R. Tampubolon, E. P. S. Parapat, E. I. Malau, and D. S. Hutagalung, "Decision support system for selection technique using MOORA method," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1088, no. 1, p. 012022, 2021, doi: 10.1088/1757-899x/1088/1/012022.

[28] N. KUNDAKCI, "Selection of maintenance strategy for a manufacturing company with fuzzy moora method," no. Mcdm, pp. 1–14, 2020, doi: 10.33422/2nd.icbmeconf.2019.06.1028.

[29] W. K. M. Brauers, E. K. Zavadskas, Z. Turskis, and T. Vilutiene, "Multi-objective contractor's ranking by applying the moora method," *J. Bus. Econ. Manag.*, vol. 9, no. 4, pp. 245–255, 2008, doi: 10.3846/1611-1699.2008.9.245-255.

[30] T. Barik, S. Parida, and K. Pal, "Optimizing the input parameters setting for least hole defects while drilling CFRP laminates by multi-objective optimization on the basis of ratio analysis (MOORA) method," *J. Phys. Conf. Ser.*, vol. 2484, no. 1, 2023, doi: 10.1088/1742-6596/2484/1/012007.

[31] D. D. Trung, "Expanding Data Normalization Method To Codas Method for Multi-Criteria Decision Making," *Appl. Eng. Lett.*, vol. 7, no. 2, pp.

54–66, 2022, doi: 10.18485/aeletters.2022.7.2.2.

[32] A. T. Nguyen, “Expanding the Data Normalization Strategy to the MACONT Method for Multi-Criteria Decision Making,” *Eng. Technol. Appl. Sci. Res.*, vol. 13, no. 2, pp. 10489–10495, 2023, doi: 10.48084/etasr.5672.

[33] C. P. Wei, P. Wang, and Y. Z. Zhang, “Entropy, similarity measure of interval-valued intuitionistic fuzzy sets and their applications,” *Inf. Sci. (Ny).*, vol. 181, no. 19, pp. 4273–4286, 2011, doi: 10.1016/j.ins.2011.06.001.

[34] E. Roszkowska, M. Filipowicz-Chomko, A. Łyczkowska-Hanćkowiak, and E. Majewska, “Extended Hellwig’s Method Utilizing Entropy-Based Weights and Mahalanobis Distance: Applications in Evaluating Sustainable Development in the Education Area,” *Entropy*, vol. 26, no. 3, 2024, doi: 10.3390/e26030197.