The Evaluation Method of Electric Scooter Design Solutions

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Abstract: To tackle the challenges of uncertainty and subjectivity in evaluating electric scooter modeling schemes, this study introduces an innovative decision-making framework that integrates the Social Network Analysis-Group Decision Making (SNA-GDM) model with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Initially, a comprehensive evaluation index system is established, followed by the determination of index weights to facilitate the selection of the optimal scheme. Analysis of practical cases demonstrates the proposed approach's ability to overcome the inherent limitations of traditional evaluation techniques. The validation of the optimal electric scooter modeling scheme provides valuable insights for future research, development, and design endeavors in this field. The integrated evaluation method, which combines SNA, GDM, and TOPSIS, exhibits significant advantages and practical applicability. By addressing the drawbacks of the conventional TOPSIS method, such as data sensitivity and subjectivity, and enhancing the objectivity and accuracy of the expert group evaluation through the introduction of the SNA-GDM model and consensus adjustment mechanism, this method represents a substantial improvement in the evaluation of electric scooter modeling schemes.

Keywords: evaluation of electric scooter modeling Schemes; SNA-GDM model; TOPSIS method; comprehensive evaluation index system

1. Introduction

In the development process of electric scooters [1-4] and the view of the diversity of the knowledge background of the developers and the wide distribution of their professional fields, there are often a variety of alternatives, which can meet the established design requirements to varying degrees. However, due to objective factors such as resource allocation, technical feasibility and market acceptance, enterprises often need to identify and implement the optimal solution [5]. This process requires not only a deep understanding of the strategic objectives of the enterprise [6], but also a scientific and systematic evaluation mechanism [7] to ensure the effectiveness and accuracy of decisions.

This paper consists of the following parts: In section 1, a brief introduction of this paper. In section 2, a briefly introduction about some related research results of product modeling evaluation. In section 3, detail description of evaluation method of electric scooter modeling scheme. In section 4, A case of evaluation of electric scooter modeling scheme. In section 5, the conclusions and future research direction are discussed.

2. SNA-GDM-TOPSIS model

The content of this model is mainly divided into three parts, one is the construction of the evaluation index of the electric scooter modeling scheme, the second is the determination of the weight of each evaluation index, and the third is the optimization and optimization of the specific modeling scheme of the electric scooter.

2.1. Evaluation index construction

To obtain objective and independent evaluation indicators for the design of electric scooters, this paper adopts the Delphi method to construct the evaluation indicators. The Delphi method [8] is a decision-making approach that utilizes the collective wisdom of experts through anonymous inquiries and feedback mechanisms. It is a cyclical process involving anonymous questioning of experts, feedback of group opinions, and further questioning of experts until a consensus is reached. Due to its anonymity and consistency, the Delphi method is widely applied in areas such as technological development, market demand, strategic planning, and risk assessment [9].

To cover the theoretical design [10], production and manufacturing, and usage feedback of electric scooter styling, the invited experts should meet the following requirements: first, they should be engaged in theoretical research related to styling design; second, they should have worked in the electric scooter professional field for three years or more; third, they should use electric scooters for more than one hour daily. According to the above requirements, 20 experts were invited to participate in the construction process of the evaluation indicators for electric scooter styling, including 5 practitioners, 8 users, 2 master's thesis supervisors in the field of styling design, and 5 master's students. Information was collected in a back-to-back manner. First, the purpose was clarified as the construction of the first-level evaluation indicators for electric scooter styling. Then, the opinions of the 20 experts were asked for multiple rounds. Finally, through adding differential items, deleting irrelevant items, and merging similar items, four first-level indicators for electric scooter styling, namely function, appearance, safety, and cost, were obtained.

Based on the above four primary indicators, through market research and literature analysis, the Affinity Diagram method [11] was used to collect users' demands for the styling of electric scooters, thereby establishing the user demand space. The user demand space is shown in Table 1.

Tab. 1 User demand space for the styling of electric scooters

Functional Indicator	Appearance Indicator	Safety Indicator	Cost Indicator
1.Foldable 2.Strong endurance capacity 3.Removable battery 4.Adjustable seat 5.Capable of carrying people 6.Standing with feet side by side 7.Navigation function 8.Waterproof function 9.Shock absorption performance 10.Storage function	1.Personalized design 2.Simple and smooth styling 3.Rich color options 4.Appealing to general aesthetics 5.Strong body texture	1.Intelligent anti-theft system 2.Equipped with auxiliary wheels 3.Low chassis center of gravity 4.Sturdy and safe body 5.Easy to operate 6.Lightweight body 7.Safety helmet 8.Eco-friendly and healthy materials used 9.Anti-tipping capability	1.Affordable price 2.Low power consumption 3.Easy to repair 4.Long battery life 5.Replaceable battery 6.High resale value

Based on the user demand space for electric scooter design, the "Wen Juan Xing" platform was utilized to distribute an online questionnaire to users aged 18-50. The questionnaire content focused on user age and the importance of various elements within the user demand space for electric scooter design under the primary indicators. The survey was conducted anonymously. Using the Likert 5-point scale [25], the five levels of importance for each element – "Absolutely Necessary," "Needed," "Neutral/Indifferent," "Unacceptable," and "Absolutely Not Allowed" – were assigned values of 5, 4, 3, 2, and 1 points, respectively.

A total of 305 questionnaires were collected from this survey. After excluding blank questionnaires, invalid questionnaires that did not meet the age requirement, and those with malicious evaluations, the final count of valid questionnaires was 242. Reliability analysis was conducted on the results of the valid questionnaires using Python. The Cronbach's Alpha [26] coefficient for the questionnaire data was 0.835, which is greater than 0.7, indicating that the questionnaire data is authentic and reliable.

The scores for each element were summed and ranked. The top three elements under each of the four primary indicators were selected as the secondary indicators for evaluating the design of electric scooters. The final evaluation index system for electric scooter design is illustrated in Figure 1.

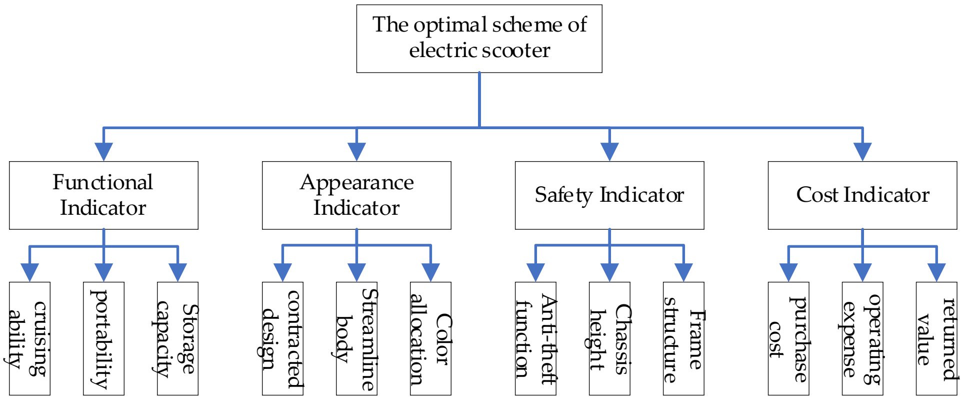

Fig. 1 Evaluation index of electric scooter shape

2.2. Determine indicator weights by using SNA-GDM

Social Network Analysis (SNA) [27] is a quantitative analysis method used to study the characteristics of social structure and relational patterns. Its advantage lies in its ability to comprehensively analyze and consider the complex interactions and multi-layered relationships among micro-individuals, between individuals and macro-collectives, as well as among different collectives, thereby providing an in-depth understanding of the overall network structure. However, a disadvantage of SNA is that social network data is often difficult to obtain, especially for large-scale networks. Group Decision Making (GDM) [28] refers to the decision-making process in which a decision-making collective composed of multiple individuals participates. Compared to individual decision-making, GDM offers more comprehensive decision-making information and higher acceptability of decision outcomes. Nevertheless, its drawbacks include unclear division of labor and importance among members, weak subjectivity among members, and a tendency for decision-making errors due to conformity pressure.

By comprehensively considering the advantages and disadvantages of the above two methods, we can construct a social network using a defined expert group to address the difficulty of obtaining network data. Additionally, we can determine expert weights based on the social network to solve the issue of unclear member importance. The organic integration of these two methods forms a relatively scientific and comprehensive SNA-GDM approach for determining indicator weights.

Based on group decision making in a social network environment, the evaluations of multiple experts are integrated through knowledge fusion. The fusion process is illustrated in Figure 2 below.

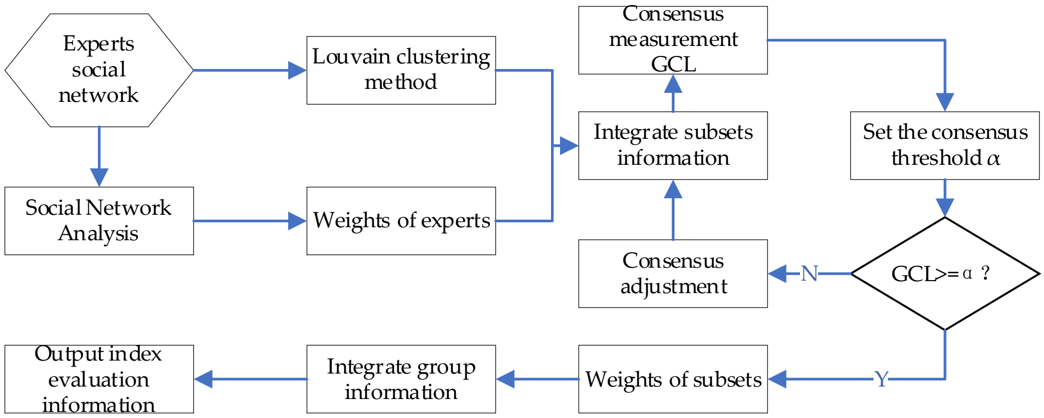

Fig. 2 Flow chart of SNA-GDM modelling

Step 1: Constructing the Expert Social Network. In this step, we utilize Social Network Analysis (SNA) techniques to assemble a group of experts and determine their weights based on the importance of nodes within the network. The weights of experts are calculated by considering the degree centrality [29] and closeness centrality [30] of nodes. The specific calculations are as follows:

$$\omega_{ei} = \frac{1}{2}(D_{ei} + C_{ei}) \quad (1)$$

Where Dei and Cei represent the normalized degree centrality and closeness centrality of expert node i, respectively.

In this paper, the Louvain clustering algorithm [31] for community detection is employed to aggregate the expert group. The basic idea of this algorithm is to maximize modularity. The Louvain algorithm not only maintains high clustering accuracy but also significantly reduces computation time, making it advantageous in both clustering quality and speed for applications in social network analysis.

Step 2: Integrate the subsets' information. In this step, subset knowledge fusion is performed, where subset knowledge is defined as the weighted sum of expert knowledge within each subset. The specific calculation is as follows:

$$V(C_i) = \sum_{ei \in C_i} \omega_{ei} \bullet V(ei) \quad (2)$$

Where V(Ci) represents the indicator evaluation information for subset Ci, and V(ei) represents the indicator evaluation information for expert ei.

Step 3: Setting Consensus Threshold α and Calculating Consensus Measurement. In this step, a consensus threshold α is set, and a consensus measure is calculated to represent the level of group consensus. The higher the consensus measure, the higher the level of group consensus, which leads to more objective and universally applicable decisions made by the group. In this paper, the distance between the average indicator of the expert group and the optimal indicator is used as the consensus threshold. The consensus level of the cluster is measured by calculating the second-order Minkowski distance [32] between the subset and the optimal indicator. The calculation is as follows:

$$\alpha = d(\overline{V(e_i)}, C^*) \quad (3)$$

$$GCL = \#C^{-1} \sum d(C_i, C^*) \quad (4)$$

Where V(ei) represents the evaluation information of expert ei, #C denotes the number of subsets after clustering the expert group, C* represents the optimal solution for the importance of each evaluation indicator, which is composed of the maximum expert scores for the same indicator, and d(Ci, C*) represents the second-order Minkowski distance between the evaluation information of subset Ci and the optimal solution.

Step 4: Group Knowledge Integration [33].When the group consensus level reaches a predetermined degree, i.e., when the consensus measure meets or exceeds a certain threshold, group knowledge fusion is performed. Group knowledge is defined as the weighted sum of subset knowledge. In this paper, the weight of a subset is considered to consist of two parts: the clustering coefficient of the subset and the number of experts in the subset. The calculation of group knowledge is as follows:

（5）

（6）

Where ISCi represents the total clustering coefficient of subset Ci, #Ci denotes the number of experts in subset Ci, and V(Ci) represents the evaluation information of subset Ci.

Step 5: Consensus Adjustment. When the group consensus level does not reach the predetermined degree, i.e., when the consensus measure falls below the threshold, the consensus adjustment mechanism is triggered. The first step in the consensus adjustment process is to identify the individual experts within subsets that require adjustment. Specifically:

（7）

（8）

Where adj_C represents the subset that requires adjustment, and adj_e represents the expert within that subset who requires adjustment. The expert ei within the subset that has the greatest distance from the optimal indicators is identified as the expert needing adjustment.

For the expert requiring adjustment, the following strategies can be adopted to adjust their evaluation information:

（9）

Where Vt(ei) represents the evaluation information of expert ei before adjustment, and θ represents the expert's degree of confidence, which is generally set to 0.5 in this paper for simplicity.

Step 6: Consensus Reached and Output of Scoring Scheme. After iterative adjustments, the expert group reaches a consensus and outputs a scoring scheme for the 12 indicators. To obtain the weights of the indicators, the scores in this scheme are normalized.

2.3. Evaluation of the SNA-GDM-TOPSIS Scheme

TOPSIS is a classic multi-attribute evaluation method widely used in engineering, management, economics, and other fields due to its superior universality, objectivity, and comprehensiveness [34]. The implementation process of combining TOPSIS with SNA-GDM is illustrated in the diagram.

Fig. 3 Flow chart of SNA-GDM-TOPSIS modeling

Invite the aforementioned 20 experts to score the 12 indicators of the alternative schemes shown in Figure 1 using a 10-point scale (ranging from 1 to 10) and input the scores into the SNA-GDM model. The model will then output the scoring results for the alternative schemes after reaching a consensus among the experts. Based on whether the indicators are cost-oriented or benefit-oriented, standardize the scoring results. After standardization, calculate the positive and negative ideal solutions, and determine the closeness of each alternative scheme to these ideal solutions. Subsequently, select the optimal scheme based on this closeness.

Step 1: Standardize the Evaluation Matrix .To avoid the impact of different dimensions on decision-making, the initial data is standardized based on cost-oriented and benefit-oriented indicators. Equations (10) and (11) represent the standardization calculation methods for cost-oriented and benefit-oriented indicators, respectively. After standardization, the evaluation matrix is denoted as .

（10）

（11）

Step 2: Define the Positive and Negative Ideal Solutions. In the standardized evaluation matrix , the positive ideal solution represents the best possible values for all indicators which is described as , while the negative ideal solution represents the worst possible values which is described as . Here, the subscript n denotes the n indicators used to evaluate the electric scooter design schemes.

Step 3: Calculate the Closeness Degree. In this step, we need to calculate the closeness degree of each alternative to the positive ideal solution. The calculation method is as follows:

（12）

Where the subscript i represents the i-th alternative, n represents the n-th indicators, and ωj represents the weight of the j-th indicator obtained in Section 2.2.

Step 4: Select the Optimal Scheme. In this step, the scheme with the highest closeness degree to the positive ideal solution is considered as the optimal scheme.

3. Case Analysis

3.1 Sample Selection

In this paper, mainstream electric scooter products currently available on the market are selected, and among them, four products with distinctive features in terms of design are chosen as the experimental samples for this case study.

a）S1　　b）S2　　c）S3　　d）S4

Fig. 4 Sample alternative

As shown in Figure 4, Sample 1 features a novel style with a seated driving position and foldable design; Sample 2 has a minimalist structure with strong battery life and foldability; Sample 3 boasts strong battery life and high body stability; and Sample 4 offers excellent storage capacity, a seated driving position, and ergonomic design.

In this paper, a 10-point scale (ranging from 1 to 10) is adopted, and 20 experts are invited to participate in the evaluation of electric scooter design schemes. They are asked to pre-score 12 indicators, focusing solely on the importance of each indicator related to electric scooter design, rather than specific schemes. Due to space limitations, only partial scoring results are presented in Table 2.

Tab. 2. The sheet of index scoring

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
E1	10	1	2	6	7	7	4	6	8	9	7	7
E2	2	2	9	6	8	3	1	4	3	5	3	7
E3	4	2	5	5	6	4	6	2	5	5	8	7
E4	7	4	1	10	10	5	8	3	7	4	6	6
E5	9	7	3	2	5	6	3	5	4	3	1	6
E6	1	1	2	8	2	1	7	7	5	10	1	6
E7	8	7	4	6	7	8	3	7	2	5	1	5
E8	8	8	10	8	4	1	10	2	7	10	3	3
E9	3	7	2	7	6	7	5	3	7	1	9	5
E10	9	9	2	2	5	5	6	8	4	4	8	1
E11	3	4	5	1	10	9	10	10	4	9	5	4
E12	3	7	6	7	2	3	8	2	3	4	7	4
E13	3	3	2	2	7	4	9	10	6	3	2	2
E14	5	5	8	1	8	7	4	6	5	7	9	2
E15	5	4	9	9	7	6	9	7	8	6	4	2
E16	6	6	3	3	5	3	3	2	6	10	9	7

E17	4	6	6	4	8	5	7	3	7	2	3	6
E18	9	8	1	7	8	9	6	5	8	4	9	2
E19	6	7	9	8	3	4	1	5	3	10	4	7
E20	7	4	6	6	7	2	8	9	10	9	9	8

The scoring results from Table 1 are input into the SNA-GDM model. After several iterations to reach a consensus, the output results are shown in Table 3.

Tab. 3 The score and weight of electric scooter index

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
Score	6.177	5.485	5.290	5.882	6.945	5.514	6.351	6.044	6.026	6.327	5.827	5.086
Weight	0.087	0.077	0.075	0.083	0.098	0.078	0.090	0.085	0.085	0.089	0.082	0.072

3.2 Selection of Optimal Scheme

To ensure the consistency and accuracy of the scoring results for the scheme indicators, the same 20 experts are invited to score the 12 indicators of the scheme samples shown in Figure 4 based on a 10-point scale (ranging from 1 to 10). Due to space limitations, this paper presents partial scoring results for each sample scheme in Table 4.

Tab. 4 Index score table of samples

a） Indicator scoring table of S1

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
E1	8	2	5	6	4	1	4	8	6	8	9	6
E2	2	9	7	8	4	8	5	2	6	2	10	1
E3	3	7	9	6	4	7	5	7	5	10	6	10
E4	4	8	2	9	5	10	1	3	10	8	5	1
E5	1	9	5	4	9	8	1	9	8	5	1	5
E6	3	8	3	7	4	4	10	8	4	5	7	6
E7	9	9	2	10	4	5	2	7	3	8	8	1
E8	4	5	2	7	6	4	5	8	4	2	2	9
E9	2	4	2	3	4	4	3	4	4	9	10	6
E10	2	10	7	9	8	1	2	2	4	5	2	5
E11	1	3	9	3	1	4	5	2	6	6	5	4
E12	7	2	8	5	2	10	7	1	6	4	6	9
E13	7	7	4	8	6	2	5	4	8	10	1	7
E14	2	3	1	3	10	5	8	6	1	9	4	9
E15	6	6	1	4	2	3	9	1	5	1	2	10
E16	5	1	2	9	6	8	9	4	2	9	3	6
E17	3	9	3	2	3	3	4	9	5	5	6	10
E18	4	6	5	8	4	3	1	7	3	9	2	5
E19	5	4	3	7	3	7	6	8	8	5	4	5
E20	7	3	7	2	8	3	6	1	3	6	9	8

b） Indicator scoring table of S2

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
E1	5	3	10	10	10	1	7	9	1	7	7	9
E2	9	4	7	5	2	7	1	3	1	8	2	9
E3	10	4	9	3	1	9	4	2	2	6	10	9
E4	5	9	6	6	1	4	7	5	2	10	5	9
E5	9	3	10	10	2	2	5	1	7	3	7	1
E6	7	5	3	6	4	5	10	2	1	5	10	7
E7	2	3	2	8	4	4	7	3	2	7	10	10
E8	4	6	6	9	3	6	3	2	3	6	8	9
E9	9	10	7	5	3	1	8	1	3	7	2	3
E10	3	6	6	1	5	4	3	7	7	2	2	2
E11	1	6	4	3	2	1	3	2	10	7	2	2
E12	5	3	6	2	10	3	8	4	4	3	2	7
E13	9	9	8	3	8	6	1	4	8	4	4	10
E14	3	7	4	10	4	2	3	5	5	9	2	9
E15	8	5	10	3	7	6	2	2	1	7	6	8
E16	2	4	1	9	1	8	8	5	6	2	5	7
E17	9	9	6	4	7	3	7	6	4	4	5	3
E18	4	8	3	9	4	7	9	10	2	4	1	2
E19	8	9	7	7	9	9	3	8	9	1	3	9
E20	2	9	9	4	1	5	4	2	1	8	2	3

c） Indicator scoring table of S3

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
E1	6	4	10	8	8	9	6	6	8	2	8	1
E2	1	9	1	10	2	9	1	4	7	9	3	9
E3	7	7	10	9	1	9	2	9	3	10	4	2
E4	4	9	6	3	6	1	8	10	4	9	2	9
E5	2	8	10	10	9	4	7	2	3	4	3	7
E6	8	7	3	9	1	8	7	4	4	9	6	9
E7	5	2	6	5	5	9	2	6	2	7	3	6
E8	8	8	8	6	8	6	5	2	9	1	10	6
E9	5	3	2	10	2	10	6	9	9	8	2	6
E10	9	3	5	9	7	6	6	9	3	9	5	9
E11	6	6	3	1	6	5	10	5	6	10	3	10
E12	7	7	3	6	1	8	1	10	9	6	7	10
E13	8	7	3	10	2	5	4	1	7	7	1	5

E14	5	9	5	5	5	1	2	9	10	9	5	5
E15	2	5	7	1	5	5	6	1	10	3	5	3
E16	7	9	9	2	7	3	8	7	4	7	1	1
E17	3	4	7	3	5	9	2	8	7	8	3	4
E18	7	9	6	4	6	4	10	10	7	7	3	5
E19	5	7	9	7	5	2	3	4	1	3	1	5
E20	6	3	7	6	7	6	10	5	1	5	1	9

d） Indicator scoring table of S4

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
E1	8	4	3	8	8	4	8	4	2	2	5	3
E2	1	3	2	8	3	4	1	8	1	8	7	1
E3	6	6	1	7	2	3	6	2	6	3	9	4
E4	6	4	9	3	10	4	8	1	4	6	9	1
E5	2	5	6	3	10	7	1	2	1	2	8	9
E6	7	10	3	7	3	3	2	4	8	7	10	10
E7	9	9	10	3	8	7	4	4	9	1	8	3
E8	8	5	3	8	9	7	4	4	1	10	1	5
E9	6	10	1	2	9	9	3	6	4	4	3	8
E10	10	7	1	6	7	9	7	4	4	8	8	4
E11	7	2	7	5	3	3	6	8	10	4	2	7
E12	3	1	2	2	2	7	6	2	5	6	2	1
E13	8	6	5	9	4	1	9	3	8	3	6	2
E14	5	9	4	8	7	6	7	2	7	10	8	9
E15	8	9	9	4	3	6	10	9	5	6	1	8
E16	8	6	5	1	4	5	3	9	6	1	7	2
E17	4	5	2	6	9	5	7	8	6	10	7	8
E18	3	3	3	6	9	5	5	8	9	7	10	1
E19	3	4	9	9	3	1	1	8	4	7	4	10
E20	9	4	8	5	8	3	6	6	8	1	9	2

The scores given by the 20 experts for the indicators of Samples 1-4 are input into the SNA-GDM model separately. After repeated iterations and adjustments to reach a consensus among the experts, the final scores for the scheme indicators agreed upon by the expert group are obtained, as shown in Table 5.

Tab. 5 Score table of samples

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
S1	4.72	6.41	4.74	6.45	5.52	5.64	5.28	5.67	5.72	6.87	6.08	6.30
S2	6.27	6.95	6.58	6.38	5.02	5.20	5.94	4.92	4.37	6.19	5.40	6.92
S3	6.16	6.48	6.40	6.66	5.49	6.34	6.13	6.71	5.83	7.32	4.43	6.75
S4	6.50	6.16	5.20	5.87	6.64	5.19	5.63	5.34	6.04	5.61	6.85	5.60

The scores in Table 5 are standardized. It is evident that U8, U10, and U11 are cost-type indicators, while the remaining indicators are benefit-type indicators. According to Equations 10 and 11, the weighted and standardized scores for the samples are obtained as shown in Table 6.

Tab. 6 Standardized score table of samples

	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	U11	U12
S1	0.00	0.32	0.00	0.73	0.31	0.39	0.00	0.58	0.81	0.26	0.32	0.53
S2	0.87	1.00	1.00	0.65	0.00	0.01	0.78	1.00	0.00	0.66	0.60	1.00
S3	0.81	0.41	0.90	1.00	0.29	1.00	1.00	0.00	0.87	0.00	1.00	0.87
S4	1.00	0.00	0.25	0.00	1.00	0.00	0.41	0.77	1.00	1.00	0.00	0.00

Based on Table 6, the positive ideal solution and negative ideal solution are determined as

and . Using Equation 12, the Euclidean distances between each sample and the positive and negative ideal solutions are calculated, and then the closeness degree of each sample to the positive ideal solution is obtained. The results are shown in Table 7.

Tab.7 The comprehensive closeness of the sample

Sample	DS^+	DS^-	E
S1	0.40	0.19	0.323770661
S2	0.30	0.47	0.610221226
S3	0.25	0.53	0.677025625
S4	0.47	0.34	0.421352908

From Table 7, we can see that E3 > E2 > E4 > E1. Therefore, it can be determined that Sample 3 is the optimal design scheme for the electric scooter.

3.3 Analysis of the Optimal Scheme

he bar chart can visually and effectively highlight differences between data. The scores for each indicator of S1 to S4 shown in Table 5 are plotted into a bar chart, with each sample represented by a different color. The result is shown in Figure 5.

Fig. 5 The index score of each sample

As shown in Figure 5, Sample 3's competitive advantages are mainly concentrated in four areas: design style, color matching, chassis structure, and maintenance cost. However, there are still areas for improvement. For example, in terms of purchase cost and portability, optimizations can be made by referring to Sample 2. The final concept scheme is shown in Figure 6.

Fig. 6 Optimized conceptual scheme

As seen in Figure 6, the new scheme primarily adopts a matte black as the main color, complemented by a metal-textured frame. It inherits the high chassis and three-wheel hub features of Sample 3, while eliminating the front wheel suspension to reduce costs. Additionally, a foldable steering lever is designed to improve its portability.

4. Conclusion

This paper proposes a method for selecting the optimal design scheme for electric scooter aesthetics based on SNA-GDM-TOPSIS. Firstly, a scientific and comprehensive evaluation index system for electric scooter aesthetics is constructed through Delphi method, affinity diagram method, combined with market analysis and questionnaire surveys. Subsequently, social network analysis techniques are introduced to calculate the weight of each expert. Then, each expert pre-scores the importance of each evaluation index for each scheme, and a consensus is reached among the expert group through a large group decision-making model to obtain scores. From this, the weight values of each evaluation index for the electric scooter design schemes are determined. Finally, the closeness of each sample to the ideal solution is calculated to select the best scheme. Based on the best scheme, a new electric scooter design is generated by integrating the expert group's selection behavior for various indicators of electric scooters.

Compared to the traditional TOPSIS method, this paper introduces social network analysis techniques and a large group decision-making model to calculate the weights of evaluation indicators, effectively avoiding subjectivity and arbitrariness when experts select design schemes. This approach mitigates the sensitivity of traditional TOPSIS to data and enhances the objectivity of the optimal scheme, providing a certain degree of universality for the subsequent product launch. Meanwhile, the method proposed in this paper also has certain reference significance for the evaluation of other types of design schemes.

In the process of determining indicator weights, this paper still has issues such as not considering the adjustment willingness of experts to be adjusted and not considering the dynamic changes in expert preferences. In subsequent research, these issues will be taken into consideration to achieve further practical application effects.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, author-ship, and/or publication of this article.

Data Sharing Agreement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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