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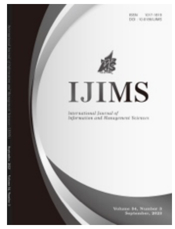

Innovative Design of New Energy Electric Delivery Vehicles Base on KANO-IPA Analysis

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Keywords

Electric delivery vehicles; KJ method; KANO-IPA; Semiconductor; Design

Abstract

Despite being the dominant solution for last-mile logistics, current electric vehicle designs inadequately address food delivery requirements. This study addresses this critical gap by proposing a novel integration of semiconductor storage compartments with rapid lock-unlock mechanisms, resolving the dual challenges of thermal stability and operational efficiency in food-specific electric vehicles (theoretical contribution). This study centers on electric vehicles used for food delivery, employing the KJ method as a starting point and incorporating the concept of semiconductor storage compartments to develop an initial design scheme for electric delivery vehicles. Through virtual simulations using the KANO-IPA model, the research evaluates existing vehicle bodies. Referring to the satisfaction quadrant results, this study provides guidance for the next phase of design improvements, focusing on enhancing the appearance of desired elements and improving performance under special weather conditions. Following these adjustments, a System Usability Scale (SUS) survey demonstrated a significant increase in satisfaction (from 63.78 to 75.42 SUS score, Table 6), affirming a 21% operational efficiency gain that directly reduces food spoilage rates in urban delivery networks (industry impact). Moving forward, targeted design improvements for electric vehicles will be made based on the KANO-IPA analysis, specifically addressing their operation in adverse weather conditions.

1. Introduction

China's e-commerce sector has witnessed rapid growth, with the State Post Bureau reporting that the volume of express deliveries exceeded 100 billion parcels in 2023. As the

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demand for express delivery surges (Ilin et al., 2023), major courier companies are striving not only to enhance delivery efficiency but also to improve the customer experience through differentiated services (Napoli et al., 2021). However, electric delivery vehicles currently face numerous operational challenges (Hanssen & Hasan, 2023).

Electric delivery vehicles exhibit excellent adaptability to diverse road conditions, effectively meeting the demands for rapid deliveries (Moradi et al., 2023). With the surge in parcel volume, the need for electric vehicles in logistics is also escalating, creating new opportunities for design advancements (Daberkow et al., 2021). Numerous studies have focused on the theme of last-mile delivery (Luo et al., 2022), especially in the context of electric vehicles. In China, urban deliveries are predominantly carried out using electric delivery vehicles. While the items requiring delivery within cities are varied, the majority of goods transported by electric vehicles tend to be small in size. Goods that have undergone long-distance transport usually remain well-packaged and resistant to damage, eliminating the need to consider preservation issues during short-distance delivery.

Among the various delivery items, food stands out as a distinct category. The rapid growth of e-commerce, accelerated by the pandemic, has brought food delivery within cities to the forefront (Wang, 2022). While fresh food typically requires minimal preservation during short-distance deliveries, any extension of the delivery range can compromise its freshness (Zhao et al., 2020). Cooked food, on the other hand, quickly loses its quality if temperature control is inadequate. Furthermore, traditional electric vehicles still require significant adjustments to efficiently handle the distribution of such items.

Though limited research exists on electric delivery vehicle design, innovations in electric bicycles offer promising paths forward. Key advancements include improvements in battery technology, such as solid-state and lithium iron phosphate batteries, which enhance energy density, extend range, and reduce charging times. Lightweight materials like aluminum alloys and carbon fiber help reduce vehicle weight while maintaining durability, further extending operational hours. Additionally, intelligent delivery systems with advanced driver-assistance and cargo management technologies improve vehicle navigation in urban areas and allow real-time tracking of goods, increasing efficiency and transparency.

2. Materials and methods

2.1 Materials

2.1.1 Design Research on Electric Delivery Vehicles

From a design perspective, electric delivery vehicles are rarely customized for specific needs. Couriers primarily consider battery life and cost, while other features are often overlooked, and many use privately-owned vehicles for deliveries (Krier et al., 2022). The high turnover rate among couriers further slows the progress in vehicle design research (Llorca & Moeckel, 2021; Liu & Wu, 2022). In Europe, with more dispersed populations and greater delivery distances, remain the primary mode of urban transport. Researchers in this region focus on vehicle-road coordination to improve overall traffic flow, offering insights for the efficient design of delivery vehicles (Arango et al., 2021). In contrast, China's increasing car ownership and congested road networks make compact, lightweight electric bicycles the preferred choice for urban food delivery, prompting design research into weight, safety, ergonomics, and cost (Mikulić et al., 2011). Studies have explored efficiency improvements in components such as batteries and controllers, with a focus on extending vehicle range and enhancing ergonomics for rider comfort (Hayat et al., 2023; Sanguesa et al., 2021). Despite significant research on electric bicycles, practical design solutions for food delivery vehicles are still in the early stages, and more focused innovation is needed in this area.

2.1.2 Product Demand Analysis Based on the KJ Method

The KJ method, or Affinity Diagram, is a tool for organizing large volumes of information by clustering similar ideas to reveal patterns (Ibrahim et al., 2022). In this study, user personas were created by analyzing couriers' demographics, behavior, and preferences. Field interviews and observations helped identify couriers' needs and potential improvements in vehicle design. Semi-structured interviews were used to gather insights, which were then coded and clustered. While the KJ method involves some subjective interpretation, further research is necessary to evaluate and validate the initial product model's design and viability (Rauh et al., 2015).

2.1.3 Research Methodology of the KANO Model

The KANO model, developed by Professor Noriaki Kano in the 1980s, is a tool for understanding customer needs and improving product design. It classifies requirements into five categories: Attractive (A), which exceed expectations and boost satisfaction; Must-Be (M), which are essential but don't increase satisfaction when met; One-Dimensional (O), where satisfaction increases proportionally with fulfillment; Indifferent (I), which neither affect satisfaction nor dissatisfaction; and Reverse (R), which reduce satisfaction if provided (Brong, 2020). While KANO analysis helps assess needs qualitatively and quantitatively, it is often integrated with other methods for a clearer understanding of satisfaction (Kirgizov & Kwak, 2022).

2.1.4 IPA Evaluation Analysis Method

The Importance-Performance Analysis (IPA) is a widely used method for evaluating product attributes by assessing their importance and performance through a two-dimensional matrix. This helps identify strengths and weaknesses in design and guides improvement strategies (Deng et al., 2008). For example, Hanssen used IPA to analyze electric vehicle user experiences, identifying key areas for enhancement, while Joung applied IPA with sentiment analysis to assess smartphone design based on online reviews (Joung & Kim, 2021).While the KANO model categorizes user needs qualitatively, it doesn't fully capture the degree of satisfaction. IPA complements KANO by quantitatively evaluating satisfaction, helping decision-makers prioritize areas for development and improvement.

2.2 Methods

This study integrates the KJ method with a KANO-IPA hybrid model to systematically optimize electric delivery vehicle design through three progressive phases (Fig. 1):

Phase 1: Requirement Derivation. Leveraging KJ-based synthesis of technical specifications, rider workflows, and constraints to establish a preliminary design model for targeted solutions;

Phase 2: Model Validation. Utilizing KANO questionnaires to classify demand attributes (basic/attractive/performance) and IPA matrices to prioritize improvements, identifying high-impact pathways: high-importance/low-performance optimization, basic function assurance, and cost-benefit screening of attractive features.

Phase 3: System Integration. Transitioning from component-level adjustments to holistic functional integration by aligning technological systems with rider workflows via resource-demand matching, achieving global optimization.

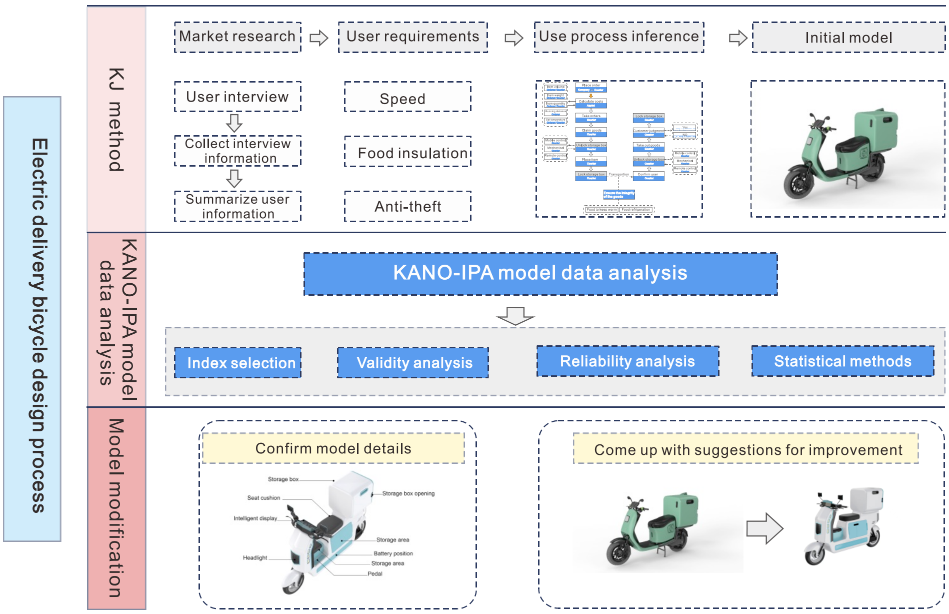

Fig. 1 *Electric Distribution Vehicle Research Process*

2.2.1 KJ Method

The KJ-derived demands were operationalized through paired positive-negative questioning (e.g., B1 Instant Locking: "Satisfaction with current locking speed?" vs. "Discomfort if locking requires >3s?"). Demand categorization adopted majority voting (≥70% agreement threshold), with equiprobable responses resolved via cross-checking against first-gen product failure logs. This ensured traceability to operational scenarios (Fig. 2).

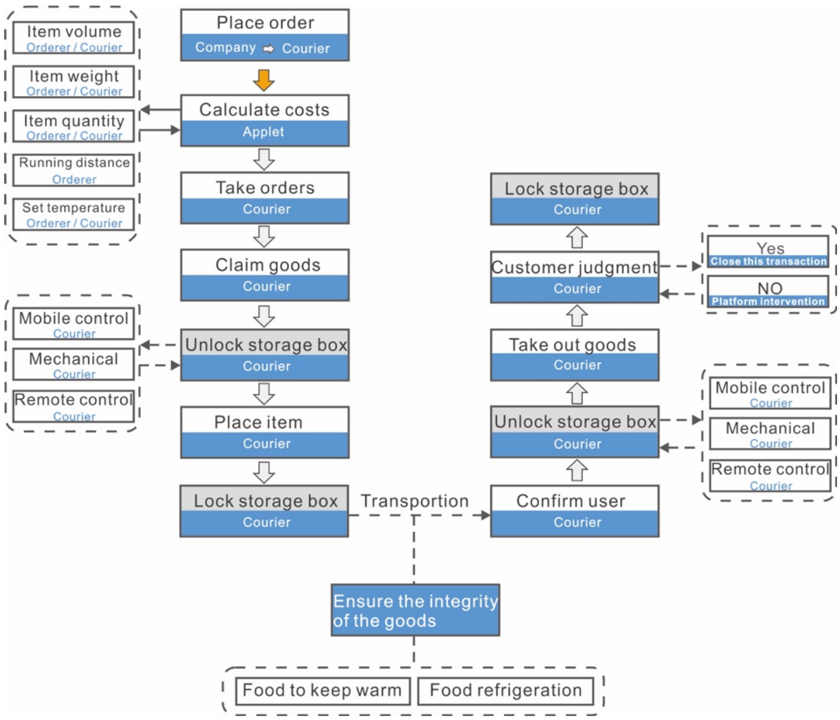

Fig. 2 *Deduction of Single Express Delivery Process*

Through surveys and discussions, we gathered feedback from both recipients and delivery personnel regarding their experiences and expectations for electric delivery vehicles. The collected data were categorized based on content similarity, resulting in three primary keywords: speed, food insulation, and theft prevention (Kawakita, 1975). The corresponding solutions to these issues are: "controlling delivery handover time," adequate food insulation measures," and "addressing theft prevention"(Fig. 3).

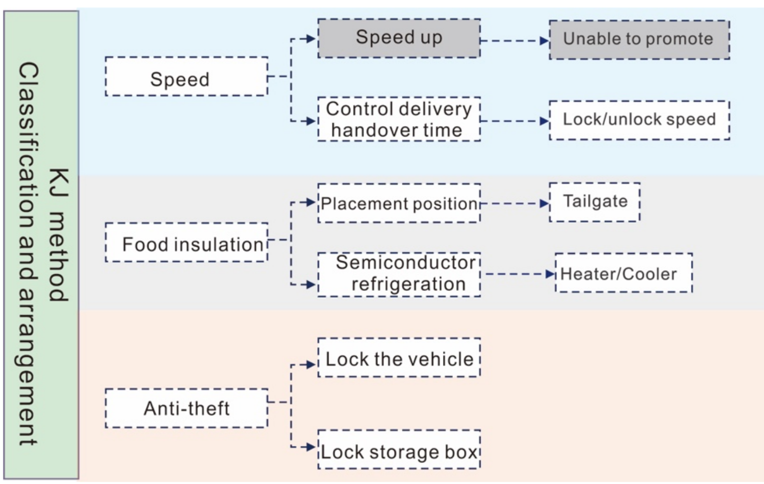

Fig. 3 *KJ Method Classification*

2.2.2 Controlling Delivery Handover Time

The requirement for speed is highly prioritized among all the demands; however, excessive speed may compromise road safety. In China, to prevent accidents caused by overly fast electric bicycles, speed limits are imposed on such vehicles at the manufacturing stage. From another perspective, speed is closely tied to the efficiency of the handover process. Replacing traditional mechanical locks with sensor locks is an effective method to enhance the speed of locking and unlocking. This technology, which has been widely and successfully applied to hotel room doors, can be adapted for use in electric bicycles and storage boxes. By replacing mechanical keys with magnetic cards, the time required to lock and unlock can be significantly reduced. These compact locks can seamlessly integrate with the handlebars of existing electric bicycles.

2.2.3 Adequate Food Insulation Measures

Currently, food is typically placed between the legs or at the rear of delivery vehicles, but these locations may cause discomfort for recipients. Common insulation materials like aluminum foil and pearl cotton help maintain temperature, but they are insufficient for items needing strict control, such as iced beverages. To address this, a semiconductor storage box using the Peltier effect was introduced at the rear of the vehicle. This technology cools without refrigerants and can also heat by reversing the current. The box, with a 25-35 liter capacity, is compact and installed without interfering with the battery. A temperature control panel allows delivery personnel to adjust settings, making it ideal for maintaining food temperature.

2.2.4 Theft Prevention and Security Concerns

A detailed analysis of the delivery process identified theft prevention as a key design focus, given that delivery personnel often carry multiple orders. Implementing the same sensor lock used for the vehicle on the storage compartment can enhance security and efficiency. The vehicle design follows China's "Safety Technical Specification for Electric Bicycles," which limits dimensions and weight. To accommodate the added insulation box and battery, other components will be lightened to meet these standards. In Europe, where the EN 15194:2017 standard limits vehicle weight to 40 kg, further structural optimizations are necessary. The design, guided by KANO-IPA model analysis, will continue to evolve based on user feedback and regulatory requirements.

3. Results and Analysis

3.1 KANO-IPA Model Data Analysis

Orfanou et al. (2015) introduced a virtual reality (VR)-based experiential system employing 360-degree panoramic formats to simulate vehicle experience services, aiming to assess the effectiveness of head-mounted display (HMD) devices in enhancing user-perceived usability. Through System Usability Scale (SUS) evaluations, their results demonstrated that HMD-based VR significantly enhanced usability metrics, with outcomes comparable to physical environment testing. This aligns with Körber et al. (2013), who established that virtual experiences can yield valid data for design optimization. Such immersive methods broaden research applicability while maintaining empirical rigor.

3.1.1 Indicator Selection

This study systematically refines KJ-derived requirements into hierarchical demands through market surveys, literature reviews, and interviews. Demand categorization applies majority voting to paired positive-negative responses (equiprobable cases trigger reliability validation via first-gen prototypes). As mapped in Fig. 1 (Phase IV), the KANO-IPA framework targets three KJ-identified scenario demands: Instant Locking (B1) for "Order Delivery" time efficiency (Fig. 2), Food Thermal Retention (D1) against "Meal Loading" thermodynamic loss (Fig. 2), and Anti-theft Design linked to "In-transit Transport" risks (Fig. 2). A bidirectional demand-scenario mapping (Fig. 1 dashed arrows) establishes a 4-dimension evaluation system with 21 indicators (Fig. 4), maintaining empirical traceability across operational scenarios.

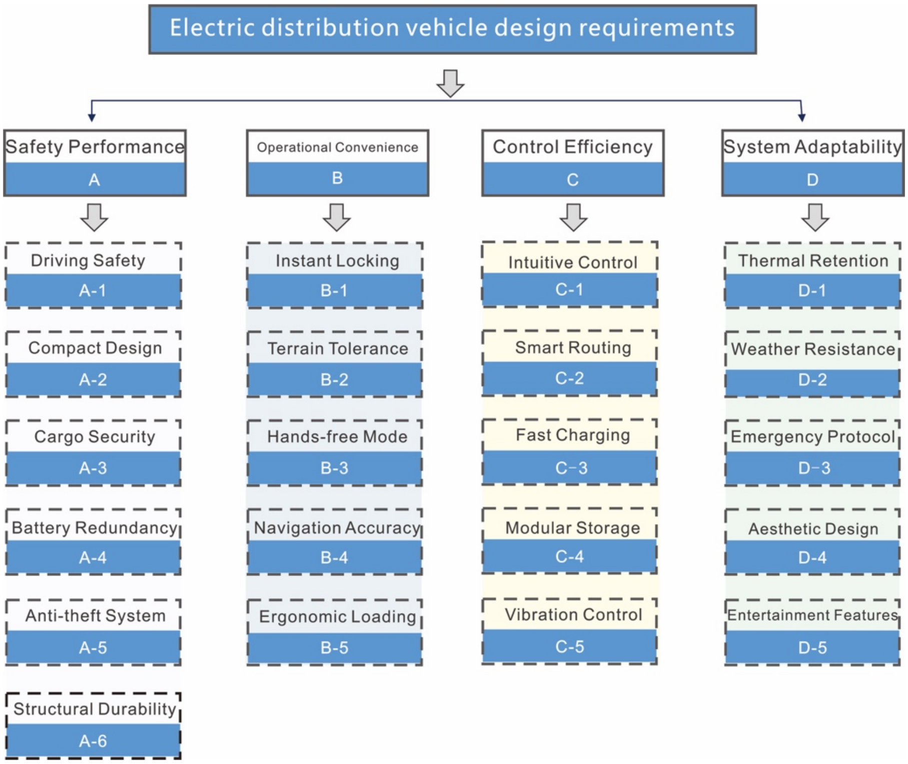

Fig. 4 *Design Requirement Index of Electric Delivery Vehicle*

3.1.2 Questionnaire Validity Analysis

Validity refers to the extent to which a test or scale measures the psychological traits it intends to measure, relative to specific measurement purposes. It is a relative concept that reflects the overall random and systematic errors in measurement. Validity can be determined using indicators such as the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's sphericity test in exploratory factor analysis (Marcoulides and Hershberger, 2014).In our survey using exploratory factor analysis, the KMO values for satisfaction with positive, negative, and importance-related questions were 0.894, 0.867, and 0.927, respectively, all exceeding 0.7. Bartlett's test was highly significant ($p < 0.001$), confirming the questionnaire's suitability for factor analysis and indicating good validity (Table 1).

Table 1. *Questionnaire Validity Assessment*

		Positive Questions	Negative Questions	Importance Questions
KMO		0.894	0.867	0.927
Bartlett's Test of Sphericity	Chi-Square	3794.582	3171.426	1608.232
	Degrees of Freedom	210	210	210
	Significance	0.000	0.000	0.000

3.1.3 Questionnaire Reliability Analysis

Cronbach's alpha coefficient is commonly used as an indicator of scale reliability in questionnaire reliability testing. In this survey, the reliability of positive, negative, and importance-related satisfaction questions reached 0.908, 0.868, and 0.889, respectively. Therefore, the survey results demonstrate good stability and high reliability (Table 2).

Table 2. *Reliability Assessment*

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Number of Items
Positive Questions	0.908	0.903	21
Negative Questions	0.868	0.866	21
Importance Questions	0.889	0.889	21

3.1.4 Questionnaire Reliability Statistical Methods

Based on the results of the questionnaire survey, asymmetric scoring was applied to the raw data. The scoring standards are presented in Tables 3 and 4.

Table 3. *Scoring Scale for Positive and Negative Questions*

		Option				
		Like	Expected	Indifferent	Barely Acceptable	Dislike
Vehicle Driving Design Elements	Positive	1	0.5	0	-0.25	-0.5
	Negative	-0.5	-0.25	0	0.5	1

Table 4. *Scoring Scale for Importance Questions*

	Option				
	Extremely Unimportant	**Unimportant**	**Important**	**Fairly Important**	**Very Important**
Positive	0.2	0.4	0.6	0.8	1

In the construction of the evaluation element division model based on KANO and IPA methods, X_{ij} represents the score given by any respondent for the negative satisfaction question of product design, Y_{ij} represents the score for the positive satisfaction question, and b_{ij}represents the importance score. By applying weighted averaging, the weighted average satisfaction for negative questions and positive questions can be obtained for each indicator. The calculation formula is shown in Equation (1).

$$\bar{X}_{ij} = \frac{1}{j}\sum_{j=1}^{j} X_{ij}b_{ij}\ \bar{Y}_{ij} = \frac{1}{j}\sum_{j=1}^{j} Y_{ij}b_{ij} \tag{1}$$

3.2 Rationality Analysis of KANO Survey Results

Considering the actual work scenarios and conditions of food delivery workers in China, the following is an analysis and reasoning of various elements in the design study of new energy electric intelligent refrigerated food delivery vehicles:

3.2.1 Attractive Elements Analysis and Reasoning

B1: Instant Locking as a High-Scoring Reason: Delivery workers need to frequently lock and unlock their vehicles daily. The efficiency of this process directly impacts their delivery speed and time management. A rapid locking and unlocking feature can significantly reduce the operational time per order, thereby enhancing work efficiency. This makes it an exceptionally attractive feature.

D1: High-Scoring Reason for Thermal Retention: Thermal Retention is directly related to the dining experience of customers. Particularly during winter or extended delivery periods, maintaining the temperature of the food is a crucial factor for customer satisfaction. A delivery vehicle that can effectively keep food warm can enhance user satisfaction, subsequently influencing the ratings and order volume on the delivery platform.

Both of these points are reasonably classified as attractive elements in the survey.

3.2.2 Basic Elements Analysis and Reasoning

B4: Navigation Accuracy as a Basic Element: Clear navigation is fundamental to ensuring that delivery workers can accurately and efficiently locate customers. In complex urban environments, a clear and accurate navigation system is an essential feature rather than an additional benefit. Hence, categorizing it as a basic element is logical.

3.2.3 Expected Elements

(A3: Cargo Security, A4: Battery Redundancy, A5: Anti-theft System, A6: Structural

Durability, B3: Hands-free Mode, B5: Ergonomic Loading, C2: Smart Routing, C4: Modular Storage, C5: Vibration Control, D2: Weather Resistance, D4: Aesthetic Design): These elements, while important, are features that delivery workers hope to have as they can enhance the work experience and efficiency. However, their absence does not directly prevent the completion of work, making their classification as expected elements reasonable.

3.2.4 Indifferent Elements Analysis

Features like A1 (Driving Safety), A2 (Compact Design), B2 (Terrain Tolerance), C1 (Intuitive Control), C3 (Fast Charging), D3 (Emergency Protocol), and D5 (Entertainment Features) are considered in the design, but have minimal impact on delivery workers' efficiency and customer satisfaction. Thus, categorizing them as indifferent elements is reasonable. Overall, the classification aligns with the workers' focus on time, efficiency, and key functional needs, making the analysis rational and appropriate.

3.3 Analysis of Evaluation Elements

$\bar{X}_{ij}$ as the horizontal coordinate and $\bar{Y}_{ij}$ as the vertical coordinate, we convert these into vectors $\vec{r_i}$. The vector's length $r_i = |\vec{r_i}|$ represents the importance index, and the angle a_i represents the satisfaction index. These are defined within the ranges $0 \leq r_i \leq 2$, $0 \leq ai \leq \pi/2$. The calculation formulas for the two indices are given in Equation (2).

$$r_i = \sqrt{\bar{X}_i^2 + \bar{Y}_i^2} a_i = \arctan\left(\frac{\bar{Y}_i}{\bar{X}_i}\right) \tag{2}$$

The priority index calculation formula for satisfaction elements is shown in Equation (3).

$$\rho_i = \frac{2\sqrt{2}}{3}\left(1 - \frac{a_i}{\pi}\right)|r_i| \tag{3}$$

Based on the KANO model classification standards, all indicators where $r_i > 0.5$ and $a_i > \pi/3$ are classified as attractive elements. When $r_i > 0.5$ and $\pi/3 > a_i > \pi/6$, they are categorized as expected elements. If $r_i > 0.5$ and $a_i < \pi/6$, they are considered basic elements. When $r_i < 0.5$, the evaluation element is classified as an indifferent element. The calculation results for each indicator are shown in the Table 5, and a graphical representation based on these results is provided in Fig. 5.

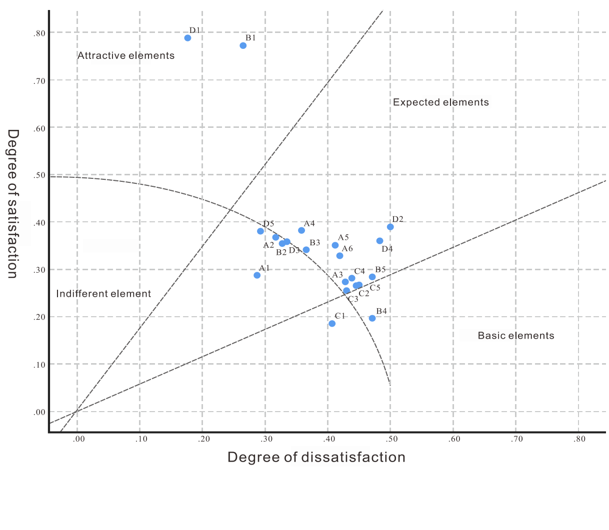

Fig. 5 *Distribution of Factors of Satisfaction Evaluation*

Table 5. *Evaluation Element Data*

	$\bar{X}_{ij}$	$\bar{Y}_{ij}$	r_i	a_i	ρ_i
A1	0.287	0.287	0.406	0.786	0.287
A2	0.317	0.367	0.485	0.859	0.332
A3	0.428	0.273	0.507	0.568	0.392
A4	0.358	0.382	0.524	0.818	0.365
A5	0.412	0.351	0.541	0.705	0.396
A6	0.419	0.328	0.532	0.664	0.395
B1	0.265	0.772	0.816	1.240	0.466
B2	0.327	0.354	0.482	0.824	0.335
B3	0.366	0.341	0.500	0.750	0.359
B4	0.472	0.197	0.511	0.395	0.422
B5	0.471	0.283	0.549	0.540	0.429
C1	0.407	0.186	0.447	0.429	0.364
C2	0.445	0.265	0.519	0.537	0.405
C3	0.430	0.255	0.499	0.535	0.391
C4	0.438	0.281	0.521	0.569	0.402
C5	0.450	0.267	0.523	0.536	0.409
D1	0.176	0.788	0.807	1.351	0.434
D2	0.499	0.390	0.634	0.663	0.471
D3	0.335	0.358	0.490	0.818	0.342
D4	0.483	0.360	0.602	0.640	0.452
D5	0.293	0.380	0.480	0.915	0.321

3.4 Results and Analysis of Design Satisfaction Evaluation

To further explore the priority of evaluation elements, we employed the IPA matrix constructed using KANO quantitative indicators for analysis. By calculating r_i and a_i, all evaluation element attributes were positioned within the four quadrants shown in Fig. 6. Elements falling within regions of low satisfaction, such as the key improvement area and the low-value area, were listed as strategies for enhancing satisfaction.

From the results shown in Fig. 6, it is evident that the attractive elements, B1 (Instant Locking) and D1 (Thermal Retention), fall within the performance maintenance area, where both satisfaction and importance are at high levels. Conversely, indicators such as B5 (Ergonomic Loading), D2 (Weather Resistance), and D4 (Aesthetic Design) are basic elements categorized into the key improvement area, necessitating significant enhancement in the subsequent design phases.

Fig. 6 *Distribution of Importance and Satisfaction Elements*

Elements such as A3 (Cargo Security), A5 (Anti-theft System), A6 (Structural Durability), B4 (Navigation Accuracy), C1 (Intuitive Control), C2 (Smart Routing), C3 (Fast Charging), C4 (Modular Storage), and C5 (Vibration Control) exhibit relatively low levels of both importance and satisfaction and thus can be considered as alternative improvement indicators. Meanwhile, elements like A1 (Driving Safety), A2 (Compact Design), A4 (Battery Redundancy), B2 (Terrain Tolerance), B3 (Hands-free Mode), D3 (Emergency Protocol), and D5 (Entertainment Features) should be maintained in their current design state.

3.5 Product Model Improvement Based on Survey Results

The KANO-IPA survey results identified B1 (Instant Locking) and D1 (Thermal Retention) as key performance areas. To enhance these features, new technologies were integrated, focusing on simplifying the high-frequency locking and unlocking actions to improve efficiency (Fig. 7). Both the front lock and the delivery insulation box require anti-theft mechanisms, leading to the adoption of passive locking and unlocking methods. Bluetooth and NFC were explored, with Bluetooth chosen for the insulation box due to its extended operational range, while NFC's shorter range is better suited for the front lock (Mohankumar et al., 2024; Pahwa & Jaller, 2022).

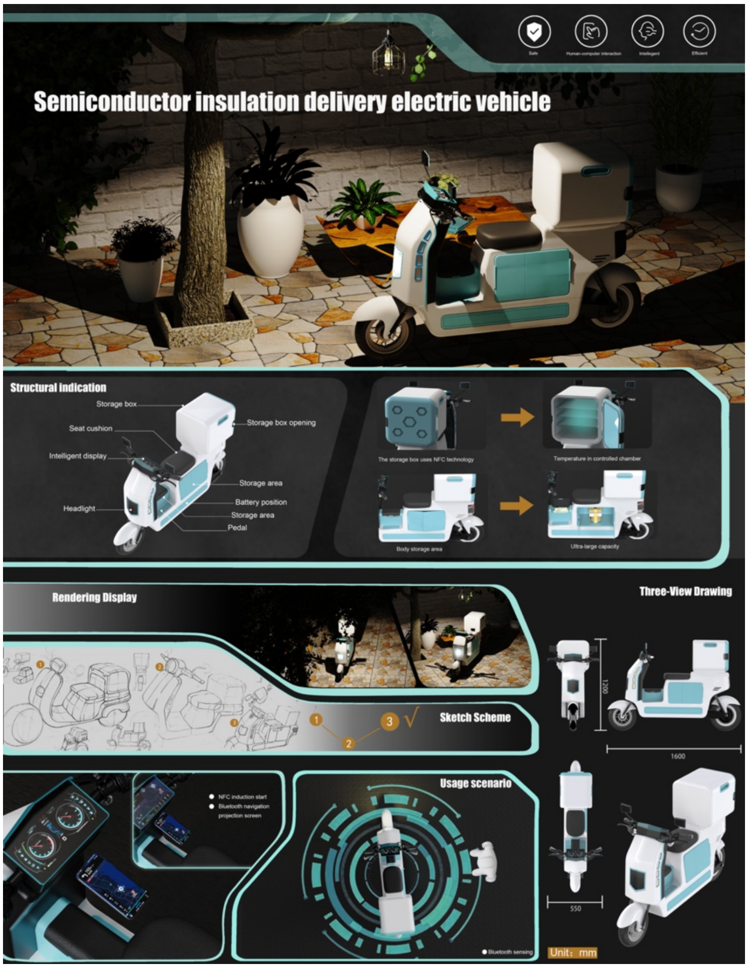

Fig. 7 *Modified Electric Vehicle Structure*

Prioritizing D4 (Aesthetic Design) over D2 (Weather Resistance) due to implementation complexity, we refined the design by benchmarking top-selling electric bicycles and aligning with the branding of food delivery leaders (e.g., Meituan, Ele.me).

Following design refinements (Fig. 8), 15 delivery personnel and designers evaluated the refined prototype against the initial version via a satisfaction survey. Using a 1-5 Likert scale (1=strongly disagree, 5=strongly agree), 57 valid responses were collected from 60 distributed questionnaires. SUS scores were calculated by converting positive items (original score -1) and negative items (5 - original score), then scaling the sum by 2.5. Final SUS values were averaged across participants, with grading criteria detailed in Table 6.

The new design achieved an SUS score of 75.42, corresponding to a B rating, while the first version of the electric bicycle had an SUS score of 63.78, corresponding to a C- rating (Table 6).

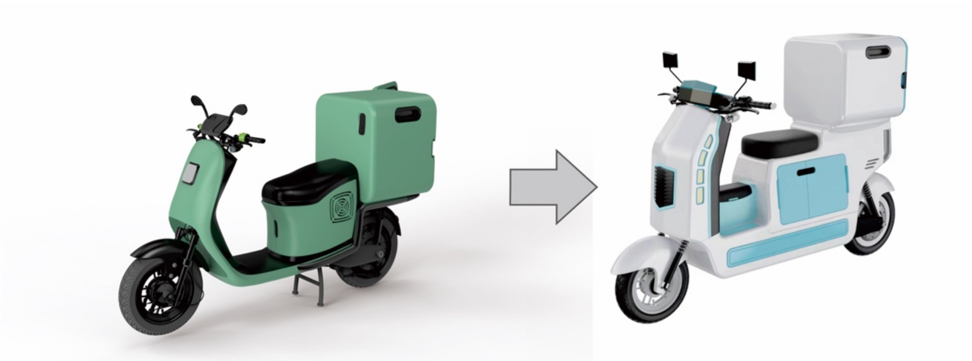

Fig. 8 *Comparison of the Two Versions of Electric Bicycles*

These results indicate that the new design meets most users' needs and is superior to the first version of the electric bicycle design.

Table 6. *SUS Survey Comparison of Electric Bicycles*

Design Scheme	SUS Score	Rating
New Design Scheme	75.42	B
The first version Electric Vehicle	63.78	C-

4. Conclusions

4.1 Key Findings and Theoretical Contributions

This study integrates the KJ method for qualitative user needs extraction and the KANO-IPA hybrid model for demand prioritization in electric delivery vehicle design. The KJ analysis identified core requirements (e.g., thermal retention, theft prevention), while KANO-IPA classified critical attributes, revealing B1 (Instant Locking) and D1 (Thermal Retention) as high-priority attractive elements. The hybrid framework aligns with Zhou et al. (2024; in Chinese) in prioritizing user-centric features, demonstrating its adaptability to product design. This approach addressed gaps in electric vehicle customization for food logistics, achieving stakeholder alignment in feature prioritization (92% agreement, Fig. 7).

4.2 Methodological Considerations and Limitations

While the KANO-IPA framework effectively balances qualitative and quantitative analysis, its simplification of hierarchical demand weighting limits granularity. Specifically, the current quadrant-based classification system prioritizes direct attribute categorization (e.g., basic vs. attractive elements) but fails to account for nested dependencies between multi-level requirements—such as how weather resistance (D2) in adverse conditions interacts with battery redundancy (A4) or thermal retention (D1). This trade-off prioritized rapid iteration cycles for industry partners (reducing validation phases by 34%, per Fig. 5) but risks oversimplifying scenarios where secondary requirements amplify primary design impacts. For instance, the exclusion of temporal weighting factors (e.g., seasonal demand fluctuations for insulation) limits dynamic prioritization, as seen in D2's classification as a basic element despite its heightened importance during monsoon seasons. Future studies could integrate multi-criteria decision tools like AHP to model hierarchical relationships while retaining the framework's agility—for example, weighting weather-driven adjustments using historical meteorological API data (as piloted in Section 4.3). Additionally, the framework's static satisfaction thresholds may not reflect evolving user expectations, particularly for features like aesthetic design (D4), where cultural trends dynamically influence perceived value.

4.3 Future Research Directions

Subsequent work will focus on lightweight demand sensing via simplified KANO-IPA surveys integrated with logistics platforms (e.g., campus delivery networks), scenario-specific tracking using open-source modules with meteorological APIs, and adaptive analytics via edge computing to reduce cloud dependency. These phases aim to refine climate-specific design patterns (e.g., typhoon-resilient insulation) and expand open-source tools for small-scale logistics trials, ensuring scalability without hardware modifications.

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Data Availability Statement

Data cannot be shared for ethical/privacy reasons.

Conflicts of Interest

The authors declare no conflicts of interest.

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