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Fire Video Interventions Reshape Electric Bicycle User Needs – A Three-Phase Identification, Prioritisation and Guidance Framework

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ABSTRACT

The global proliferation of electric bicycles (EBs) marks a significant advancement in sustainable urban transportation. However, two critical barriers impede EB's full societal integration: insufficient analysis of user needs and fire safety risks exacerbated by inadequate risk awareness. To address the above challenges, this study proposes a three-phase approach integrating user needs identification, quantitative prioritisation and risk-aware guidance to promote safer EB design practices. We establish an integrated analytical framework combining quality function deployment (QFD) with the fuzzy best-worst method (F-BWM) to achieve the first two phases-identification and quantitative prioritisation of user needs. For the third phase, we design and implement an innovative video-based guidance framework as an effective risk communication strategy, specifically targeting the enhancement of fire safety considerations during EB selection processes. Findings indicate: (1) six primary EB user needs are identified: battery and charging, handling performance, safety and security, comfort and convenience, technology and connectivity, and appearance design. (2) "Battery and charging" and "safety and security" emerge as the highest-priority EB user needs. (3) The video intervention yielded a measurable 27.73% increase in the perceived importance of fire-related features. This study provides theoretical foundations for user-centred EB design approaches.

KEYWORDS

EB user needs; user-centred approach; quality function deployment (QFD); best-worst method (BWM); video-based guidance framework.

1. INTRODUCTION

Electric bicycles (EBs) have grown rapidly worldwide, with global sales reaching 59 million units in 2022, an annual increase of 8.28% [1]. The market has become notably younger, as users under 30 account for 41.39% in China [2] and 56% in the United States [3]. This trend is especially evident among university students, for whom EBs have become the main mode of daily transport on and around campuses [4]. Accordingly, this study focuses on college students as a key user group.

EB is regarded as an environmentally friendly transport mode through lower average energy consumption, and generating fewer greenhouse gas and nitrogen oxide (NOx) emissions [5]. To further promote the environmental benefits by encouraging the use of EB, it is crucial to improve user satisfaction and experience [6]. Various stakeholders have explored numerous strategies to this end, including the construction of bike lanes by governmental bodies, improving the charging infrastructure [7][8], developing a purchase incentive program [9] and the implementation of pricing promotions by EB operators [8]. However, in EB product design, user needs such as comfort and convenience, as well as behavioural guidance, seem to have received relatively little attention. This is because the conventional approach to EB design has historically relied on optimisation methods driven by engineers and designers [10], prioritising functional criteria. However, this approach often fails to capture user needs well, resulting in user dissatisfaction. While engineers have a profound grasp of production processes and product specifications, there exists a notable disconnect between the designed products and user needs. Therefore, the key to promoting EB adoption lies in identifying users' genuine needs, prioritising these needs and translating them into relevant engineering characteristics. This shift from a technology-oriented to a user-need-oriented design approach contributes to enhancing user satisfaction, optimising the effective utilisation of engineers' expertise. It also improves both user satisfaction and the increased use of EB, resulting in environmental sustainability.

However, there are significant safety concerns to address while promoting the environmental benefits of EB. According to the National Fire and Rescue Administration [11], there were 18,000 fires involving EB reported nationwide in 2022, marking a 23.4% increase from 2021. This trend continued into 2023, with a reported 21,000 EB fires, reflecting a 17.4% increase from the previous year. From January 2021 to March 2024, a total of 69,700 fires caused by faulty EB batteries and related building fires resulted in 884 casualties. A particularly severe incident occurred on 23 February 2024, in the Yuhuatai District of Nanjing, Jiangsu Province, in China, where a fire that started on the ground floor where EBs were stored spread to six buildings, leading to 15 deaths and 44 injuries [12]. In addition, there have been similar incidents internationally. For example, an EB fire on a subway train near the Sheppard-York station on 31 December 2023, resulted in three people being taken to the hospital [13]. This means that fire-related injuries caused by EB accidents pose a serious threat not only to the users of EB themselves but also to society. Thus, to fully realise the benefits of EB, it is crucial to eliminate fire safety risks exacerbated by inadequate risk awareness, thereby achieving the dual objectives of environmental enhancement and safety.

To prevent fire-related risks, certain strategies are implemented. For example, prohibiting BE batteries from being taken upstairs for charging [14], and many colleges have gone so far as to display banners on campus to alert students about fire-related risks [15]. The strategies separate efforts to improve environmental benefits by promoting the use of EB from strategies for eliminating fire-related risks, primarily focusing on the usage process. However, there remains a gap in simultaneously eliminating fire-related risks exacerbated by inadequate risk awareness and promoting the use of EB at the design stage. This issue may raise more manufacturing costs because eliminating fire-related risks requires allocating substantial resources to EB components (namely, the batteries) directly related to fire risk. Given a certain amount of resources, if the designer or manufacturer allocates excessive resources to security, it will result in the other user needs (e.g. appearance design) not being met. This would, in turn, decrease user satisfaction, contradicting the primary objective of promoting EB usage. Furthermore, information significantly affects people's psychology and behaviour as an intervention. However, there is relatively little research on whether and how information could be used to specifically prevent fire-related injuries by guiding the needs of EB users. Given the trade-off between cost allocation and perceived importance, a behavioural intervention may be necessary to shift user priorities.

In this paper, we aim to promote EB adoption while mitigating fire-related risks through a user-centred three-phase approach. Specifically, the research (1) identifies and prioritises EB user needs based on survey data from both users and retailers, (2) introduces a video-based information intervention to enhance users' attention to fire-safety features such as battery and charging systems, and (3) evaluates the effectiveness of this approach through comparative surveys conducted before and after the intervention. This approach ultimately seeks to reduce fire-related risks while ensuring that user needs are effectively addressed.

The remainder of this paper is organised as follows: Section 2 reviews the relevant literature. The methodology is presented in Section 3. Section 4 identifies and prioritises the critical user needs, and examines whether fire videos reshape EB user need priorities. Finally, a summary of the paper and suggestions for future research are provided in Section 5.

2. LITERATURE REVIEW

The literature review includes four parts. They are studies on the benefits of EB, user satisfaction, QFD in the transportation service industry, and the impact of information on guiding psychology and behaviour, respectively.

2.1 The impacts of EB

In urban transportation, EBs exhibit both advantages and disadvantages: on the one hand, as an alternative to some motorised travel, they help reduce emissions, save energy and alleviate congestion. On the other hand, safety issues related to EBs should not be ignored either.

Environmental benefits

The impact of EB has been studied widely. In terms of promoting environmental health, Weiss et al. [16] and Aba and Esztergár-Kiss [17] argued that EB was more efficient and environmentally friendly than other motorised modes of transportation. It was estimated that EB can reduce CO_2 emissions by 225 kg per year [18]. Bai et al. [19] emphasised that in China, EB could significantly reduce energy consumption (90%), pollutant emissions (86%-95%) and carbon dioxide emissions (60%-93%) compared with private cars. EB can also help ease traffic congestion. Congestion leads to an increase in vehicular fine particulate matter (PM2.5) emissions and a steady increase in the risk of deaths associated with them over time [20]. To alleviate congestion, Bielenski et al. [21] found that residents opted for shared EB either in place of public transit or as a transport for the first/last mile between public transportation hubs. Additionally, Bigazzi and Wong [22] thought that EB could alleviate congestion by replacing cars, buses and motorcycles to a certain extent. Furthermore, based on the environmental and public health benefits of EB, Scorza and Fortunato [23] highlighted that the construction of urban cycling infrastructure could help steer urban decision-making towards active transportation modes and contribute to the process of sustainable urban development.

Safety issues

Although EB can bring obvious benefits, the potential risk of fire-related injuries caused by EB cannot be ignored. Factors such as flying line charging, overcharging and connection line failure were key triggers of EB fires [24]. Similarly, Hong et al. [25] found that thermal runaway during EB charging leads to thermal runaway propagation and further causes fires. Yu et al. [26] observed the combustion behaviour of EB and evaluated the hazards caused by battery fires in terms of combustion duration, flame spread, smoke temperature and heat release rate. Li et al. [27] showed that in an EB fire, smoke was generated rapidly in as little as 20 seconds, the flame intensified significantly at about 50 seconds, and the smoke spread rapidly up the ceiling. Carbon monoxide in the fire smoke was the main contributor to the deaths of the residents in the residential area.

Additionally, concerning EB-related traffic injury, Westerhuis et al. [28] found that EB riders faced a higher risk of fatal crashes than conventional bike riders when exposure and gender were taken into account. Wang et al. [29] used in-vehicle crash videos to analyse e-bike injury severity in China. Results showed driver violations (speeding, red-light running) and large vehicles increased injury risk, while avoidance behaviours and helmet use had protective effects. Sunshade canopies and nighttime crashes were associated with worse outcomes. Chai et al. [30] came to a similar conclusion, that EB riders were prone to ignore the effects of extreme weather on driving safety when crossing unsignalised intersections. Moreover, the higher travel speed of EB reduced riders' alertness and reaction time to potential risks, thus increasing the risk of accidents. Qian et al. [31] pointed out that the crash factors associated with EB were similar to those of conventional bicycles, such as rider fault. Liu et al. [32] emphasised that EB riders were more likely to be injured in the head, pelvis and thigh areas in vertical crashes. To effectively assess and prevent EB collisions at intersections, Wu et al. [33] proposed an innovative and comprehensive conflict intensity measure to comprehensively measure the risk and severity of traffic conflicts to improve the safety of e-bike transportation. Zou et al. [34] further investigated e-bike safety by analysing severity factors (e.g. elderly riders, intersections, mixed traffic zones) using an RP-Logit model and identifying spatio-temporal blackspots through ST-NKDE and hotspot analysis. Their findings highlighted that non-segregated road segments and intersections were high-risk zones, with temporal patterns playing a key role.

Although existing research generally recognises the hazards of EB fires, the integration of user need prioritisation and fire safety risk communication has not received sufficient attention. Therefore, this study links fire safety risk communication with the prioritisation of user needs to guide the design optimisation of EBs.

2.2 User satisfaction

Scholars have adopted various methods and theoretical frameworks to explore user satisfaction and its influencing factors. Shen et al. [35] applied the partial least squares structural equation model (PLS-SEM) to construct an evaluation model for urban rail transit user satisfaction, aiming to examine passengers' satisfaction with urban rail systems. Tyrinopoulos and Antoniou [36] used factor analysis and an ordered logit model to study satisfaction with public transport services in Athens. Maioli et al. [37] employed a service performance approach based on the dimensions of tangibility, reliability, assurance, empathy and responsiveness to evaluate user satisfaction with bike-sharing services in Recife, Brazil. Their results indicated that factors such as bicycle design, operational reliability and app compatibility had the most significant impact on satisfaction. Xia et al. [37] applied a structural equation model (SEM) to analyse the relationship between various factors and bike-sharing user satisfaction. The findings showed significant positive correlations between satisfaction and factors including environmental safety, convenience and flexibility, distribution, parking and retrieval flexibility, appearance and performance, and service quality. Shaheen et al. [39] found that public bicycle stations, real-time availability technologies, bicycle maintenance, locking mechanisms and operating hours were important factors affecting the satisfaction of shared bicycle users. Manzi and Saibene [40] took Milan BikeMi as an example and used nonlinear principal component analysis to explore the factors influencing the satisfaction of public bike-sharing services. The results show that user satisfaction was constrained by the mechanical performance of the vehicle, the pick-up and return process, and the application. Aman et al. [41], based on app store reviews, employed logistic regression to determine factors affecting e-scooter rider satisfaction. Their study revealed that rider satisfaction was influenced by ease of use, safety and app functions.

Most studies remained at the level of determining the influencing factors of satisfaction, and a few compared these factors and conducted relative importance rankings. Based on this, prioritise the EB user needs and map the key needs to achievable product features to enhance user satisfaction.

2.3 QFD in the transportation service industry

The research of QFD in the transportation service industry mainly focuses on improving service quality. Yang et al. [6] proposed a three-phase QFD framework to identify users' key needs for high-speed rail seats and to improve service quality and user satisfaction. Lam [42] developed a hybrid approach of QFD and the analytical network process (ANP) to guide shipping companies in designing sustainable offshore supply chains. Huang et al. [43] conducted an empirical study on improving liner transport service quality by using the QFD method and found that customers tend to buy complete transportation services. Wang [44] applied QFD to enhance the service quality and competitiveness of Chinese airlines. By constructing a house of quality (HOQ), the study integrated internal quality technology and external consumer voices to demonstrate the company's service performance. Yang et al. [45] proposed a framework based on QFD in a fuzzy environment for identifying, evaluating and controlling risks in the process of transporting hazardous materials. Huang et al. [46] used QFD to convert user voice into a key technical measure to improve the service quality of cross-strait high-speed ferries. Chin et al. [47] employed QFD to identify user needs to improve high-speed rail transport services. Interval-value analytic hierarchy process (AHP) was used to calculate the relative importance of the needs in this paper. Yalınız et al. [48] proposed an integrated approach combining QFD and multi-objective planning aimed at determining user needs in the streetcar system in Eskişehir, Turkey, to improve the quality of the transportation system. Soota et al. [49] constructed a bicycle product development framework based on QFD and the analytic hierarchy process (AHP) to evaluate designs that can best meet user needs. Szemere et al. [50] applied QFD to link the user needs of electric scooters with the legislative domain, thereby determining the priority of regulatory measures aimed at improving user satisfaction.

These studies have proved the utility and effectiveness of QFD in improving service quality in the field of transportation, providing the theoretical basis and application background for this paper. However, fewer studies have been conducted on personal transportation, especially EB. However, existing studies lack a clear explanation of the process of using QFD to identify user needs. For this reason, this paper integrates the SECI model with QFD to explain the specific steps of user need identification.

2.4 The influence of information on guiding psychology and behaviours

The influence of information on guiding psychology and behaviours has been commonly studied. Information interventions changed behaviour primarily by enhancing users' perception of risks, which is similar to the core idea of the health belief model (HBM) [51].

In transportation, Saedi and Khademi [52] showed that visual, auditory and textual information affect travellers' cognition differently, with visual cues proving most effective. Guo and Peeta [53] found that tailored accessibility information encouraged relocators to choose car-independent, sustainable travel options. Wright and Silberman [54] found that frequent media exposure to risky driving reduces participants' perceptions of risk, leading to an increase in their risky driving behaviours and traffic violations. Qin et al. [55] observed that emotional advertisements distracted drivers, while Lewis et al. [56] found that threat-based messages, especially for female drivers, effectively reduced speeding and drunk-driving intentions. Chebat et al. [57] further confirmed that injury-related videos improved driving behaviour and reduced unsafe actions.

Beyond transportation, information also shapes broader psychological and behavioural responses. Turel et al. [58] draw on HBM and use video to present information on the threats, susceptibility and feasible coping strategies related to Internet addiction, which improves audiences' attitudes toward reducing Internet use and, in turn, reduces and prevents excessive and problematic Internet use. Duan and Bombara [59] incorporate perceived knowledge and prior experience into the protection motivation theory (PMT) framework to identify sociopsychological factors that explain adaptive behavioural intentions related to wildfire smoke. They found that adaptive intention and perceived vulnerability were positively correlated with coping efficacy, while self-efficacy was negatively correlated with response cost. Lin et al. [60], Ge et al. [61], Cao et al. [62] and Yin et al. [63] demonstrated that short-video content enhances engagement, immersion and purchase intentions. Guo et al. [64] found that music reduces driver fatigue, with personality moderating its effects under different weather conditions.

Existing research indicates that information intervention is effective in changing behaviour. However, the explanation of its mechanism of action is still insufficient. Therefore, in the context of EB fire video intervention, this paper takes the change in user demand priority as an observable mediating indicator to reveal the mechanism of the impact of information intervention on behaviour.

2.5 Contributions

The contributions of this paper are threefold.

Firstly, existing research on EBs has focused mainly on environmental benefits, infrastructure or user satisfaction, but rarely integrates user needs and fire-safety considerations within a unified analytical framework. To address this gap, this study identifies the overlooked conflict between promoting EB adoption and mitigating fire-related risks that arise from limited user awareness and unbalanced resource allocation in product design. The proposed framework links the recognition of user needs with fire-safety awareness, offering a systematic perspective for enhancing both safety and usability at the design stage.

Secondly, prior studies using QFD in the transportation field have largely emphasised improving service quality or engineering performance, without clarifying the process of identifying and prioritising user needs for personal mobility devices. To fill this gap, this paper integrates the SECI model with QFD and the fuzzy best-worst method (F-BWM) to systematically identify and quantify user needs based on multi-source survey data from both users and retailers. This combination enables a quantitative evaluation of the relative importance of user needs, providing a practical basis for transforming user perceptions into engineering specifications.

Finally, although existing research confirms that information interventions can influence user attitudes and behaviours, the mechanism through which information reshapes user needs has not been adequately explained. To address this issue, this study introduces a video-based fire-safety intervention as a behavioural guidance mechanism and empirically examines how it alters the prioritisation of user needs. This approach bridges psychological perception and product design, demonstrating how targeted information can guide user preferences toward safety attributes without compromising satisfaction.

3. METHODOLOGY

In this paper, we propose a user-centred three-phase approach to promote EB adoption while addressing fire-related risks. This paper will focus on the application of QFD in improving the design and service of EB to provide new improvement strategies for the EB industry as a way to promote the improvement of personal transportation service quality. Specifically, the structure of the three-phase approach is shown in *Figure 1*.

According to *Figure 1*, in the first phase, we combine the socialisation, externalisation, combination and internalisation (SECI) model with QFD to identify user needs. Information gathered during QFD-based elicitation is often unstructured and hard for designers and engineers to use [6]. Therefore, we utilise the "socialisation" and "externalisation" processes of the SECI model to transform tacit knowledge into explicit knowledge [65]. This will be detailed in Section 3.1. In the second phase, we prioritise key user needs by calculating the relative importance of the user needs using the F-BWM. This will be discussed in Section 3.2.

Compared to other multi-criteria decision-making methods, the F-BWM accounts for the uncertainty and ambiguity in respondents' evaluations and only requires the construction of reference comparison vectors, thereby reducing the number of pairwise comparisons and shortening the working time [66]. In the third stage, we employ a video-based intervention to influence the prioritisation of user needs. Based on protection motivation theory (PMT) [67] and the health belief model (HBM) [68], when individuals believe that risks can be avoided by taking feasible actions (in our case, EB-related fires), behavioural change occurs. Therefore, informing people about the potential severity and susceptibility of the risk, the specific avoidance strategies, and their capability to implement these actions constitutes an effective means of encouraging healthy behaviours. Informational videos are a useful vehicle for conveying the above information and promoting behaviour change [69]. Additionally, to influence the prioritisation of user needs, we propose a guidance framework that utilises media information (specifically a video in this study) depicting fire accidents involving EB, as discussed in Section 3.3. The feasibility of this guidance in preventing fire-related injuries is verified using the same calculation process described in Section 3.2 and through a second round of data collection following the implementation of the guidance.

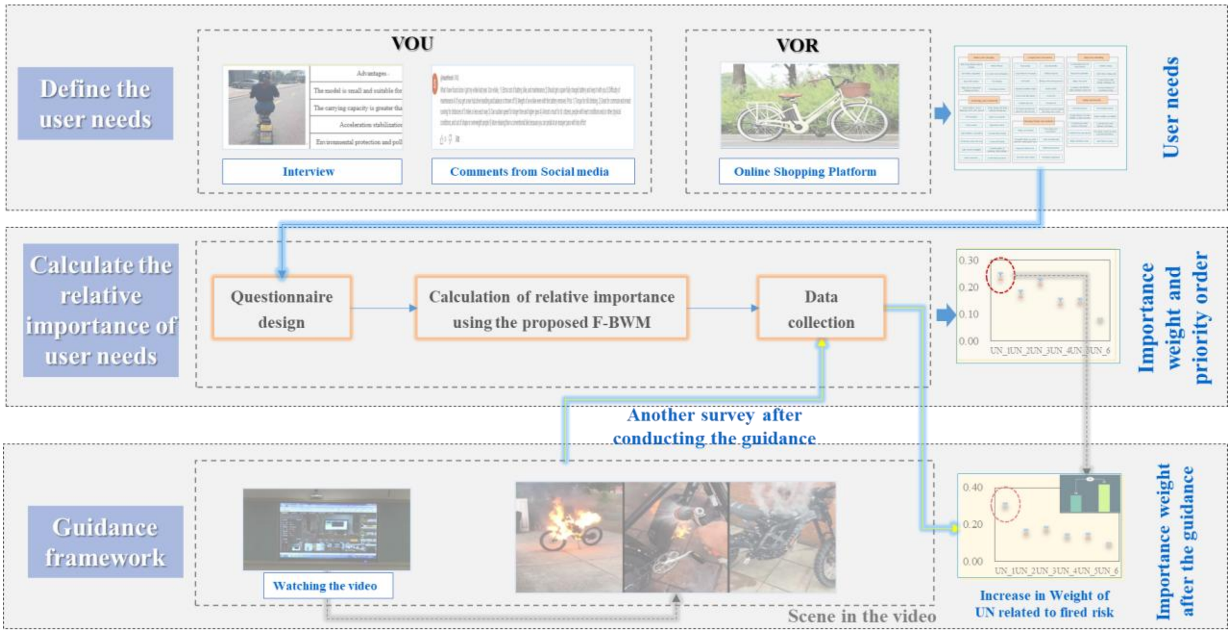

Figure 1 – The structure of the user-centred three-phase approach

3.1 Phase 1: Identify the user needs

To help designers and engineers understand user needs, this study integrates the "socialisation" and "externalisation" stages of the SECI model into the QFD framework. Through the socialisation and externalisation processes, implicit needs from interviews and social media are converted into explicit needs. This provides a foundation for subsequently converting these "explicit" user needs into product technical features and key parameters within the QFD framework. The method integrating the SECI model and QFD theory for defining user needs involves two stages: (1) socialisation, through social interactions such as interviews, transforming others' tacit knowledge into one's own tacit knowledge; (2) externalisation, which converts acquired tacit knowledge into explicit knowledge through concepts, charts and other forms. The data for the user needs identification phase come from user interviews, social media and e-commerce platforms. The data for this stage are used for empirical analysis to identify user needs.

Socialisation: The transfer of tacit knowledge into tacit knowledge

The process of socialisation has two sub-steps: first, collect the voice of the user (VOU) and the voice of the retailer (VOR), and then use the VOU & VOR table to process VOU & VOR into items of need.

First, to collect VOU more comprehensively, this paper combined three methods: user interviews, social media and commodity evaluation of online shopping platforms (such as "taobao.com", which is an online shopping website in China). These methods aim to collect users' original needs information from different channels.

1) User interview

The interview is a way to obtain information by communicating with the interviewee. Compared with traditional surveys, interviews can provide more in-depth and comprehensive data [66]. This is because interviewees can freely express their opinions in the interview, and face-to-face communication is easier to get the real needs.

In this paper, we used face-to-face interviews to collect VOU. A random sampling method was used to invite 60 college students to participate in semi-structured interviews. During the interview, respondents were invited to share their feelings about using EB. At the same time, we use digital cameras, sound recorders and other equipment to record the interview content. *Figure 2* displays an example of a live interview in this paper.

Advantages	Shortcomings
The model is small and suitable for beginners	Insufficient battery life
The carrying capacity is greater than bicycles	Long charging time
Acceleration stabilisation	Insufficient braking sensitivity
Environmental protection and pollution-free	Poor shock absorption effect

Figure 2 – Example of a user interview

2) Social media

With the rise of various social media platforms, online user reviews have become an important source of information for manufacturers [71], [72]. Therefore, paying attention to user comments posted on social media such as Weibo, Zhihu and XiaoHongshu has gradually become an important way to listen to users' opinions. Moreover, compared to traditional methods, social media collects information at almost no cost.

In the process of collecting information regarding user needs for EB, our focus was primarily on aspects concerning design and production. We used keywords such as "EB user experience", "How to purchase EB", and "EB reviews". A total of 100 user comments posted on Zhihu and Xiaohongshu during October 2023 were collected. For instance, on XiaoHongshu, a user highlighted several critical issues, including "inaccurate mileage", "small taillights", "susceptibility to rust" and "inadequate shock absorption". To enhance the product design, we systematically incorporated this feedback into our considerations.

3) Commodity evaluation of the online shopping platform

Moreover, users' needs are sometimes not immediately apparent through subjective perception alone. Users may remain unaware of certain latent needs until a product is conceptualised or presented to them. When these needs are included in the selection presented to users, they can assess the significance of these needs and provide merchants with feedback on their preferences. To capture a more comprehensive understanding of consumer demand for EB, our approach extends beyond collecting initial demand elements based on the VOU methodology from the user perspective. We also harness online shopping platforms as information channels to gather data on the functionalities and features of various EBs currently offered by retailers, namely the voice of the retailers (VOR), thereby offering a more exhaustive set of alternatives for consumer consideration. This method includes identifying features and functionalities of EB that can be showcased by retailers, enhancing the scope of consumer choices.

Online shopping platforms have become one of the main channels for people to shop. On these platforms, product reviews play a significant role. These evaluations are the authentic feedback from consumers after purchasing and using the products, thereby possessing a high level of credibility. It not only reflects consumers' perceptions of goods but also reveals their preferences and expectations. Collecting these reviews helps us better understand user needs and guide the optimisation of our products and services.

For instance, an anonymous buyer provided a review after purchasing and utilising an EB, stating, "Battery life is very good; the shock absorption effect is very good; easy to install; the quality of the goods is very good." From this evaluation, it is evident that aspects such as battery life and shock absorption are of significant importance, offering insightful information on user satisfaction and experience with the product.

At the same time, we stand on the supplier perspectives to delve into the original needs of EB users, using VOR to understand VOU deeply, aiming to grasp various factors that may influence consumer decisions more comprehensively. It is because, in certain cases, consumers may not be aware of their potential needs, but when these choices are explicitly listed, consumers can recognise these as points of concern. Such an approach helps us better understand market dynamics and enhance consumer satisfaction.

Specifically, we gather information on consumer needs based on the main product images and product details used by retailers on online shopping platforms. Retailers strategically utilise these main images and product details to spotlight the distinctive attributes of their products, underscoring essential details such as features and functions, to sway consumers' purchasing decisions. The message conveyed by these main pictures is closely related to the needs of consumers. To collect relevant information, we searched for "electric bicycles" on Taobao and Amazon, filtered out the top 100 stores according to the platform's sales rankings, and viewed the main images and product details of each store. We focus on the performance and selling points (such as battery life, charging convenience/safety, braking and lighting, etc.) that are repeatedly pinned to the top by retailers in the main store image and product detail pages, and take it as a factor that users may need to consider when purchasing EB. During this process, we manually recorded the VOR data. Additionally, we collected user comments on these stores. For example, one item on Amazon highlights battery safety performance, aesthetic design and overall safety features, and serves as a valuable reference for categorising user needs.

Externalisation: Converting tacit knowledge into explicit knowledge

Need items obtained through VOU &VOR tables may have similar associations, which are not convenient for designers and engineers to use directly. Therefore, further processing is required to obtain hierarchical and systematic user needs. The affinity diagram (or KJ method) was proposed by the Japanese scholar Jiro Kawakita [73]. Its core idea is to take disorganised textual data and group items by their internal relationships (affinity). On this basis, clearer themes and hierarchical structures are derived. This method has been widely applied in fields such as product design [74] and quality management [75]. The general steps of clustering by this method are as follows. First, each need is written on a separate card. Second, the members of the author's team collaborate to categorise needs with similar semantics or main attributes into the same category. Needs that appear to span multiple topics are excluded to avoid ambiguity. Next, based on the attributes of the needs within each category, the categories are generalised and defined, with clear boundaries established for each category. On this basis, team members discuss and ultimately determine the name of each category. During the clustering process, team members reached a consensus through collective discussion and careful consideration, thereby minimising the impact of individual subjective biases on the classification results to the greatest extent.

By grouping need items, we derived six user needs. In Section 4.1 Results of user needs, we use an affinity diagram to show the relationship between six user needs and need items.

3.2 Phase 2: Prioritise the user needs

Understanding and addressing the needs of EB users is a crucial strategy for promoting the use of EB, which subsequently enhances environmental sustainability by reducing air pollution and CO_2 emissions. To calculate the relative importance of these user needs, we collected user opinions through a questionnaire survey. Based on the data collected from the questionnaire survey, we used the F-BWM to calculate the relative importance of these needs.

Questionnaire design

The questionnaire mainly includes two parts: one is the basic information of the respondents, such as gender, and whether they own EB; the other is the survey items, that is, the respondents' assessment of the importance of user needs. Considering the uncertainty and fuzziness of the evaluations provided by the respondents, they were asked to use language terms such as "absolutely important", "very important", "moderately important", "weakly important" and "equally important" to express their opinions. The Questionnaire is shown in Appendix A.

Calculation of relative importance using the proposed F-BWM

After the previous analysis, we have identified the various needs of users for EB. Based on this, this section focuses on how to calculate the relative importance of these needs. For this purpose, our study will use the F-BWM proposed by Guo and Zhao [66] to effectively evaluate the priority of each need, thus providing precise guidance for the design and improvement of EB. This method combines the advantages of fuzzy set theory and BWM, effectively dealing with the uncertainty and fuzziness of people's subjective judgment. We will introduce the calculation process of the F-BWM method in detail.

1) Step 1: Identify the decision criteria

In this step, establish a set of decision criteria for evaluating alternative solutions first. Denote the set of criteria consisting of *n* criteria as $C=\{c_1, c_2, \cdots c_n, \}$.

2) Step 2: Decide the best and the worst criteria

Before the formal survey in Appendix A, we carried out a pre-test using the online survey platform "Questionnaire Star". The purpose of this step is to ensure the quality of the questionnaire and obtain the best and worst criteria required for calculating the relative importance using the F-BWM. The best criterion is denoted as c_B, while the worst criterion is represented as c_W.

3) Step 3: Create the fuzzy best-to-others vector

Because of the uncertainty and fuzziness in respondents' evaluations, it is necessary to develop an F-BWM. The fuzzy preference of the best criterion overall criteria can be obtained by comparing the best criterion with all criteria by reference using the linguistic terms listed in *Table 1*. Then, according to the transformation rules shown in *Table 1*, the fuzzy preference is transformed into a triangular fuzzy number (TFN) [53], which is denoted in the form of $(a_{ij}^l, a_{ij}^m, a_{ij}^u)$. The final fuzzy best-to-others vector is shown in *Equation (1)*:

$$\widetilde{A}_B = (\widetilde{a}_{B1}, \widetilde{a}_{B2}, \cdots, \widetilde{a}_{Bn}) \tag{1}$$

where $\widetilde{a}_{Bj}$ indicates a fuzzy preference for the best criterion *B* over the criterion *j*, $j=1,\ 2,\ \cdots n$ $j=1,2,\ldots,n$. It is clear that $\widetilde{a}_{BB}=(1, 1, 1)$.

According to Klir and Yuan [76] and Yang et al. [6], *Equation (1)* can be converted to *Equation (2)*:

$$\overline{A}_B = (\overline{a}_{B1}, \overline{a}_{B2}, \cdots, \overline{a}_{Bn}) \tag{2}$$

where $\overline{a}_{Bj}$ represents the preference of the best criterion *B* over criterion $j=1,2,\ldots,n$, and $\overline{a}_{BB}=[1, 1]$.

Table 1 – Transformation rules of language terms

Linguistic terms	Equally important (EI)	Weakly important (WI)	Moderately important (MI)	Very important (VI)	Absolutely important (AI)
TFNs	(1, 1, 1)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(7/2, 4, 9/2)

4) Step 4: Create the fuzzy others-to-worst vector

Similar to step 3, the fuzzy others-to-worst vector is shown in *Equation (3):*

$$\overline{A}_W = (\overline{a}_{1W}, \overline{a}_{2W}, \cdots, \overline{a}_{nW})^T \tag{3}$$

where $\overline{a}_{jW}$ represents the preference of criterion *j*, $j=1,2,\ldots,n$ over the worst criterion *W*, and $\overline{a}_{WW}=[1, 1]$.

5) Step 5: Calculate the optimal weights for the criteria ($\overline{w}_1^*, \overline{w}_2^*, \ldots, \overline{w}_n^*$)

The optimal weights of each criterion should be satisfied $\left|\overline{w}_B / \overline{w}_j - \overline{a}_{Bj}\right|$ and $\left|\overline{w}_j / \overline{w}_W - \overline{a}_{jW}\right|$. To achieve this, we aim to find a solution that minimises the maximum absolute gaps $\left|\overline{w}_B / \overline{w}_j - \overline{a}_{Bj}\right|$ and $\left|\overline{w}_j / \overline{w}_W - \overline{a}_{jW}\right|$ for any *j*. According to Rezaei [77] and Guo and Zhao [66], we established a constrained optimisation model, as shown in *Equation (4)*:

$$\begin{aligned} &\min \ \overline{\xi} \\ &s.t. \begin{cases} \left|\overline{w}_B / \overline{w}_j - \overline{a}_{Bj}\right| \le \overline{\xi} \\ \left|\overline{w}_j / \overline{w}_W - \overline{a}_{jW}\right| \le \overline{\xi} \\ \sum_{j=1}^{n} R(\overline{w}_j) = 1 \\ 0 \le w_j^l \le w_j^u, j=1,2,\ldots,n \end{cases} \end{aligned} \tag{4}$$

where $\overline{w}_B = [w_B^l, w_B^u]$, $\overline{w}_j = [w_j^l, w_j^u]$, $\overline{w}_W = [w_W^l, w_W^u]$, $\overline{a}_{Bj} = [a_{Bj}^l, a_{Bj}^u]$, $\overline{a}_{jW} = [a_{jW}^l, a_{jW}^u]$, $\overline{\xi} = [\xi^l, \xi^u]$. $R(\overline{w}_j)$ denotes the crisp value of each criterion, which is the average of the closed intervals, as shown in *Equation (5)*.

$$R(\overline{w}_j) = (w_j^l + w_j^u)/2 \quad (5)$$

Considering $\xi^l \le \xi^u$, we assume that $\overline{\xi}^* = [k^*, k^*]$. *Equation (4)* can be converted to *Equation (6)*.

$$\min k^*$$
$$s.t.\begin{cases} \left|\dfrac{[w_B^l, w_B^u]}{[w_j^l, w_j^u]} - [a_{Bj}^l, a_{Bj}^u]\right| \le k^* \\ \left|\dfrac{[w_j^l, w_j^u]}{[w_W^l, w_W^u]} - [a_{jW}^l, a_{jw}^u]\right| \le k^* \\ \sum_{j=1}^{n} R(\overline{w}_j) = 1 \\ 0 \le w_j^l \le w_j^u, j = 1,2,\ldots,n \end{cases} \quad (6)$$

By solving *Equation (6)*, the optimal weights ($\overline{w}_1^*, \overline{w}_2^*, \ldots, \overline{w}_n^*$) can be obtained, and $\overline{w}_j^* = [w_j^l, w_j^u]$.

To ensure the validity of the optimal weights, it is necessary to verify the consistency of the reference comparisons provided by the respondents. The consistency ratio (CR) is a significant index to check the degree of consistency of pairwise comparisons. Its calculation formula is shown in *Equation (7)*:

$$CR = \xi^* / CI \quad (7)$$

In *Equation (7)*, ξ^* represents the maximum absolute gap, which can be determined using *Equation (6)*, and CI denotes the consistency index. *Table 2* displays the *CI* reference of the F-BWM as introduced by Guo and Zhao [66]. In this paper, we set a threshold of 0.1 for CR. If $CR \le 0.1$, it indicates that the consistency needs for reference comparison are satisfied. This procedure functions as a formal reliability check, ensuring that the subjective pairwise comparisons made by respondents in the F-BWM are internally consistent and methodologically reliable.

Table 2 – Consistency index for F-BWM

Linguistic terms	**Equally important**	**Weakly important**	**Moderately important**	**Very important**	**Absolutely important**
$\tilde{a}_{BW}$	(1, 1, 1)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(7/2, 4, 9/2)
CI	3.00	3.80	5.29	6.69	8.04

Since the optimal weights obtained by us are represented as ranges, which are not easy to compare, the average value of the interval is selected as the crisp weight. So, the optimal weights represented by the crisp weights are ($w_1, w_2, \ldots, w_n$), and the calculation of w_j is shown in *Equation (8)*.

$$w_j = (w_j^l + w_j^u)/2, \quad j = 1,2,\ldots,n \quad (8)$$

Data collection

As both representative EB users and a key youth demographic, college students are ideal participants for offline controlled experiments [78], particularly studies requiring repeated trials. They represent a major user group whose travel behaviour and product preferences have a significant influence on the EB market. Moreover, using the same cohort of students across two survey rounds enabled a clear comparison between the control group (without video intervention) and the experimental group (with video intervention). This design ensured internal consistency between rounds and enhanced the validity of the observed intervention effects. This motivated our decision to select college students as the target group for this survey. Specifically, the initial round of data collection occurred on 7 December 2023. We conducted it face-to-face, distributing printed questionnaires to participants onsite and collecting 300 samples. This approach also set the stage for the subsequent round of research detailed in Section 3.2.3. Using the data from this first survey, we analysed the weights of different users' needs without the influence of media information. This analysis will enable manufacturers and operators to make informed decisions on resource allocation in the design of EB without the impact of additional information. Such resource allocation is anticipated to enhance user satisfaction and promote EV usage, thereby directly benefiting the environment. The sample comprised 56.67% female and 43.33% male participants.

3.3 Phase 3: Guide the priority of user needs

Additionally, our goal is to guide users in preventing fire-related injuries by prioritising battery safety. We assess the relative importance of educational videos on various user needs. To assess the impact of educational videos on preventing fire-related injuries, we also collect data through questionnaire surveys. The data were used in the empirical analysis section to determine whether the video intervention affected changes in user need weightings.

Process of guidance framework

From the perspective of information processing theory, video interventions alter individuals' perceptions of risk by influencing attention allocation, processing depth and cue interpretation [79]. Building on this foundation, we use a "video-guided framework" as a strategic tool for risk communication, aiming to increase risk awareness, educate and influence user behaviour by showcasing specific content. In this context, the framework utilises videos to highlight the safety aspects and potential risks associated with EB, particularly focusing on fire-related incidents due to battery failures. This method aims to increase user awareness and prioritise safety considerations in the decision-making process when selecting and using EB. The ultimate goal is to encourage manufacturers to address these critical safety concerns in their designs, ensuring safer products for consumers. Here is the process of the guidance framework.

First, we can engage the potential user by presenting a video highlighting fire risks, particularly those involving EB, with a serious tone. Specifically, the content of the video could be video news about fire-related injuries involving EB, using emotional appeal by presenting real accident cases and statistical data to raise viewers' awareness of fire risks. For example, in this paper, we found a video as an example. The 100-second video detailing several EB fire accidents in Shanghai in 2020 is shown in *Figure 3*. For example, according to publicly available investigative reports cited in the video, the residential building fire on Wenshui Road in Shanghai on 22 September 2020, was directly caused by a lithium battery failure when the EB was charging. Beyond this case, the video also presents an annual summary of EB-related fires in Shanghai in 2020, covering the number of incidents, the scale of casualties and the causes of the accidents.

Figure 3 – Fire accident of EB

After viewing the video, the frequent occurrence of such fire accidents not only enhances awareness of potential risks to individuals and society but also prompts people to prioritise the safety of critical components, particularly batteries, in EB to prevent injuries. Consequently, users will assign greater importance to user needs that are closely associated with fire risks.

Correspondingly, designers and manufacturers of EB will adapt their designs and production processes to reflect the increased emphasis on these user needs. Specifically, more resources will be allocated to the relevant components, especially batteries, to enhance safety and reduce the likelihood of fire-related incidents. Under the proposed guidance framework, both the supply and demand for EB will exhibit enhanced safety features. By improving the product itself, the risk of fires is reduced, thereby preventing fire-related injuries.

Verification process of the guidance framework

To evaluate the impact of media information, particularly video news about fire-related injuries, on fire accident prevention and injury mitigation, a second survey was conducted on 28 December 2023, utilising the same questionnaire detailed in Section 3.2.1. This survey was also conducted using offline questionnaires, and was conducted two weeks after the first round of surveys discussed in Section 3.2.3. Both surveys had a sample size of 300 (n = 300 before intervention; n = 300 after intervention). The respondents were college students and belonged to the same group as those in the first round of the survey. To minimise the influence of other factors, the content and distribution methods of the questionnaires in the two rounds of measurement were kept as consistent as possible. The only difference between the two rounds is the exposure of the video.

During the first survey, respondents were mainly evaluated based on their own experience and subjective feelings. At this stage, respondents' behaviour was influenced by personal opinions and actual needs. Unlike the first survey, in the second survey, we specifically included some information, such as videos and news reports about the safety of EB, particularly those involving fires, to stimulate respondents' responses.

Specifically, we invited each participant to watch the 100-second video detailed in Section 3.3.1. After viewing the video on-site, we distributed the same questionnaire as used in the first survey in Section 3.3, thereby conducting a second round of surveys. Furthermore, based on the method described in Section 3.2, we recalculated the relative importance of user needs. The first-round results were used as a control group (non-intervention scenario), while the second-round results represented the intervention scenario. By comparing changes in the weight of fire-related user needs, we analysed the effectiveness of the guidance, thereby validating the feasibility of the guidance framework proposed in Section 3.3.1. The specific analysis process will be discussed in Section 4.3.

4. EMPIRICAL RESEARCH

4.1 Identify the user needs

This paper aims to identify key needs to promote the use of EB and prevent fire-related injuries by improving user satisfaction with EB, utilising the methodology outlined in Section 3.1. Initially, we conducted data cleaning to eliminate needs unrelated to the design and production of the EB itself, such as charging infrastructure accessibility, price discounts and customer service. The cleaning work was completed by the author team. For ambiguous items, we reach a consensus through group discussions to reduce the influence of individual subjectivity. In total, we compiled 78 user-need items. After cleaning, 62 were retained and 16 were removed. Following this process, a total of 62 needed items were identified and retained for further analysis.

The needed items were grouped into the following six user needs: battery and charging (UN_1), handling performance (UN_2), safety and security (UN_3), comfort and convenience (UN_4), technology and connectivity (UN_5) and appearance design (UN_6). For a more intuitive display, the six categories of user needs are presented in *Figure 4*.

The six needs with their constituting need items are depicted in the form of affinity diagrams shown in *Figure 4*. Among these, the category "battery and charging (UN_1)" covers needs related to fire-related injuries, such as overcharge protection, high/low-temperature charging protection and slow battery degradation. Increasing resource allocation to these attributes will help reduce fire risks (methods for preventing fire-related injuries will be discussed in Section 4.3). The category "handling performance (UN_2)" focuses on riding stability, with representative items including a comfortable feel over rough surfaces and flexible steering. The category "safety and security (UN_3)" covers user needs related to traffic injury prevention, such as quick braking response and short braking distance. Enhancing these features will help improve the safety of EB users and other road users. Due to space constraints, this paper focuses solely on fire injury prevention, with traffic injury prevention to be explored further in subsequent studies. The category "comfort and convenience (UN_4)" addresses comfort and practicality in daily use, such as wide saddle and seat adjustability. The category "technology and connectivity (UN_5)" emphasises intelligence and digital interaction, such as GPS navigation and speed voice reminder. The category "design and aesthetics (UN_6)" reflects personalised preferences, with representative items including styling and aesthetics and colour options and customisation.

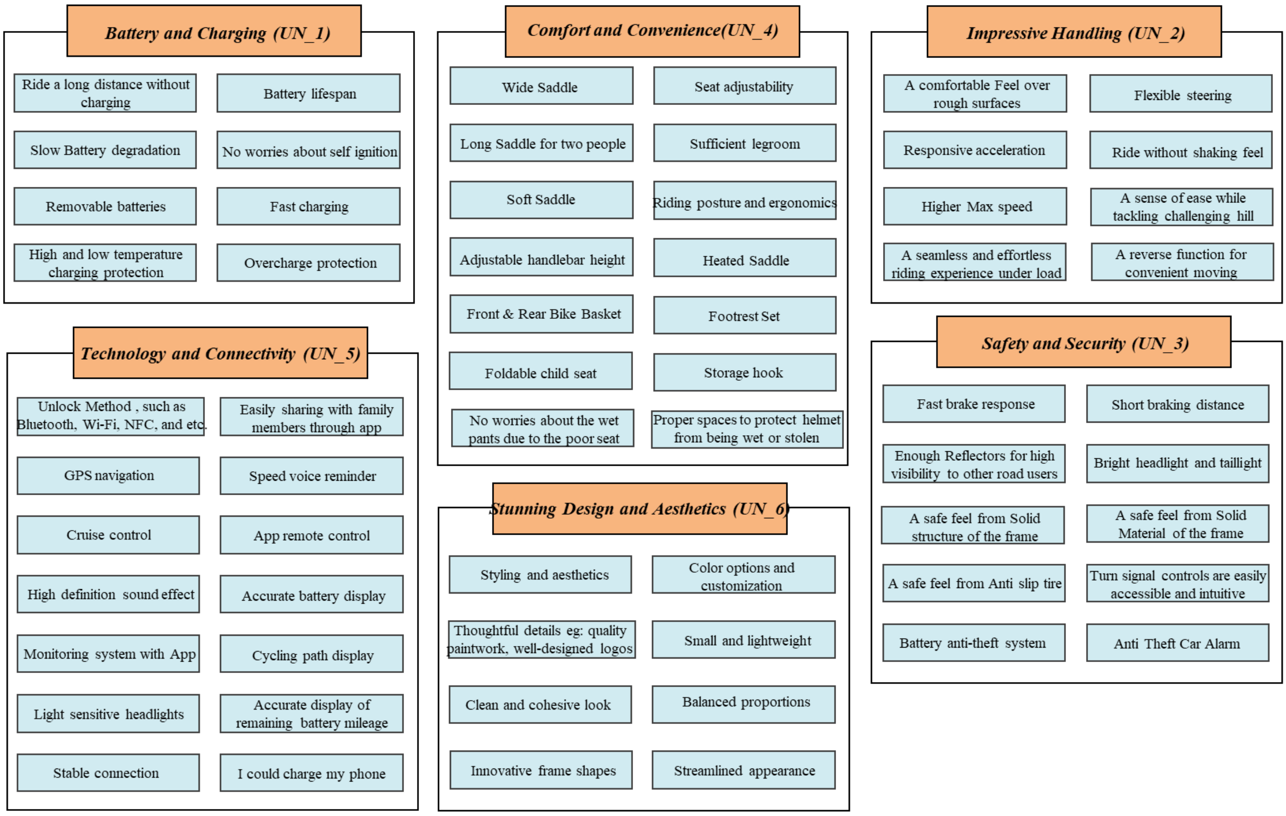

Figure 4 – Complete set of affinity diagram

Additionally, enhancing any of the six categories of user needs can improve satisfaction with EB, promote their usage, and subsequently benefit the environment. However, determining which category should be prioritised and the corresponding weight of each category will be further explored in Section 4.2.

4.2 The relative importance of user needs

Using the methodology outlined in Section 3.2, we initially conducted research focused on the analysis of the relative importance of user needs. The purpose of this analysis is to identify the significance of different users' needs, which in turn enhances satisfaction and promotes the use of EB. Ultimately, this approach aims to achieve the goal of improving the environment by improving the EB user's satisfaction.

Process of determining the weights

The relative importance of user needs can be determined by consolidating and normalising all single-importance weights. For demonstration purposes, we randomly selected one respondent from all the respondents as an example and followed the steps of the F-BWM proposed in section 3.2.3.

1) Step 1: Identify the decision criteria

To improve user satisfaction with EB, the needs of users are set as the standard. Considering six user needs, c_1 is "battery and charging", c_2 is "handling performance", c_3 is "safety and security", c_4 is "comfort and convenience", c_5 is "technology and connectivity" and c_6 is "appearance design".

2) Step 2: Decide the best and the worst criteria

After conducting a small pre-survey involving individuals who already possess EB and those looking to purchase EB, it was found that the best user need is "battery and charging (c_1)", while the worst user need is "appearance design (c_6)".

3) Step 3: Create the fuzzy best-to-others and fuzzy others-to-worst vector

Participants were asked to utilise the language terms outlined in *Table 1* to conduct comparative assessments between the best criteria and additional criteria, as well as between other criteria and the worst criterion. Then, the *α-cut* defuzzification was applied to obtain clear comparison vectors for calculation. We have included the fuzzy best-to-others and the fuzzy others-to-worst vectors for this example in Appendix B.

4) Step 4: Calculate the optimal weights for the criteria ($\overline{w}_1^*, \overline{w}_2^*, \ldots, \overline{w}_n^*$).

Considering that *Equation (6)* belongs to a nonlinear constrained optimisation problem, we use the built-in nonlinear solver of Lingo to solve it. The optimal weights for the closed interval of user needs can be obtained by solving *Equation (6)* using Lingo software. The results of the model for the sample in *Table 3* are $k = 0.802$, $\overline{w}_1 = [0.155, 0.242]$, $\overline{w}_2 = [0.240, 0.266]$, $\overline{w}_3 = [0.240, 0.266]$, $\overline{w}_4 = [0.134, 0.161]$, $\overline{w}_5 = [0.095, 0.095]$, $\overline{w}_6 = [0.053, 0.053]$.

5) Step 5: Consistency check and determine the weight of each criterion

According to *Equation (7)* in Section 3.2.2, we calculate the consistency ratio (CR) of the sample and use CR ⩽ 0.1 as the threshold to determine its validity. Since the sample passes the consistency check, we perform an arithmetic average of the interval weights of user needs to obtain the final optimal weight. The optimal weights for user needs are $w_1 = 0.199$, $w_2 = 0.253$, $w_3 = 0.253$, $w_4 = 0.148$, $w_5 = 0.095$, $w_6 = 0.053$. We will present the comprehensive importance weight of user needs in Section 4.2.2. This comprehensive weight is calculated based on the samples that have passed the consistency test through the arithmetic mean.

Analysis of the weights

The importance weights were aggregated to determine the comprehensive importance weights for each need. We calculated the consistency ratio (CR) for each respondent following *Equation (7)* in Section 3.2.2. and used CR ≤ 0.1 as the threshold for valid samples. Among the 300 questionnaires collected, 270 samples passed the consistency check and were included in the analysis. Based on these valid samples, we obtained the overall importance of user needs using the arithmetic mean. The comprehensive importance weights of the six user needs derived from the entire sample of respondents are shown in *Figure 5* and *Table 3*.

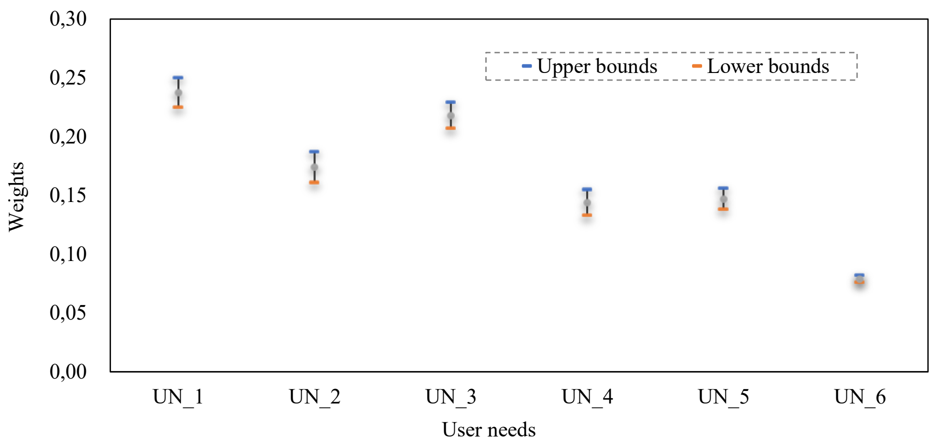

Figure 5 – Importance weights of user needs

Table 3 – Comprehensive importance weight and priority order of six user needs

User needs	**UN_1**	**UN_2**	**UN_3**
Interval value	[0.225,0.250]	[0.161,0.187]	[0.207,0.229]
Crisp value	0.238	0.174	0.218
Priority ordering	1	3	2
User needs	UN_4	UN_5	UN_6
Interval value	[0.133,0.155]	[0.138,0.156]	[0.076,0.082]
Crisp value	0.144	0.147	0.079
Priority ordering	5	4	6

Figure 5 and *Table 3* clearly show the hierarchy of user needs: UN_1 ≻ UN_3 ≻ UN_2 ≻ UN_5 ≻ UN_4 ≻ UN_6, where the symbol " ≻ " signifies "takes precedence over". It is worth noting that "battery and charging (UN_1)" and "safety and security (UN_3)" are the top two user needs, with importance weights of 23.8% and 21.8%, respectively, accounting for a total of 45.6% of all needs. This result is quite reasonable. As high–high-energy-density storage units, batteries in EBs may pose safety risks if overcharging, short circuits or thermal runaway occur during charging or discharging. These anomalies could trigger explosions or fires in a short period, endangering users' lives and property, and may create broader public risks. In addition, strengthening the safety and anti-theft design of EB can effectively reduce the occurrence of accidents and theft, to protect the personal and property safety of users. Therefore, batteries and charging, as well as safety and security, are very important. In contrast, the appearance design is the lowest priority among these six user needs, possibly because users focus more on the practicality of EB. Since EBs are mainly used for daily commuting and short trips, users tend to value functional features like range and safety more than aesthetics.

Implications for improving the satisfaction of EB users

The findings from Section 4.2.3, which present a prioritised list of user needs for EB, notably highlight "battery and charging" and "safety and security" as critical areas of concern. These insights necessitate a strategic focus from operators and manufacturers on these key aspects to improve overall service satisfaction and then promote the environmental benefits.

Additionally, the research evaluates the specific needs of EB users, along with assigning importance weights to these needs. This contribution is theoretically significant and serves as a comprehensive resource for stakeholders involved in the design, engineering, management, and even the retail and sales sectors of EB. By offering a detailed breakdown of individual user needs, this framework equips stakeholders with the nuanced understanding necessary for tailoring enhancements to meet user expectations effectively.

All stakeholders in the EB ecosystem must integrate the prioritised user needs into their strategic planning and development efforts. In particular, priority should be given to promoting the development of battery technology and enhancing the safety and security of EBs to address the issues that users are most concerned about. Interestingly, the two most critical user needs identified pertain to preventing fire accidents and traffic accidents. Addressing these needs will simultaneously help in reducing both fire-related and traffic-related injuries.

As for the EB design and management, the systematic framework developed for identifying and quantifying user needs should be employed as a guideline for making informed decisions in the design, management and improvement of EB services. This approach allows for a more user-centric development process, potentially leading to higher levels of user satisfaction and engagement.

By adopting these policy recommendations and applying the research framework, there is potential to significantly enhance the EB experience, aligning service offerings more closely with user expectations and needs. This alignment not only benefits the environment by promoting the use of EB but also contributes to preventing both fire-related and traffic-related injuries to some extent. The proposed methods for further preventing fire-related injuries will be discussed in detail in Section 4.3.

4.3 Guide the user's needs priorities by media information on fire accidents

To enhance user satisfaction and to prevent fire-related injuries associated with EB, this paper proposes a research methodology aimed at improving the users' risk awareness and furnishing policymakers and governments with pertinent evidence. The overarching goal is to improve environmental outcomes by encouraging the adoption of EB while mitigating the associated risks of fire-related injuries.

A critical focus of this research is on the characteristics that predispose EB to fire risks, thereby causing injuries not only to users but also to nearby residents. Specifically, the quality of the batteries plays a pivotal role in these incidents. It has been observed that manufacturers often prioritise investment in features that are more immediately appealing to consumers to increase market demand and, consequently, profitability. This commercial focus can sometimes overlook crucial safety aspects such as battery integrity. Therefore, this paper proposes guidance for potentially preventing fire-related injuries through targeted media interventions. These interventions aim to shift consumer attention to the importance of battery safety, which is a key feature of EB. This approach would help prevent fire-related injuries. By utilising news videos and informational campaigns that highlight the consequences of battery failures and fire-related injuries, the aim is to elevate the priority of battery safety among users. This, in turn, is anticipated to compel manufacturers to allocate more resources toward enhancing battery safety, thereby preventing fire-related injuries.

Analysis of the weights guided by videos on fire accidents

To assess the feasibility of increasing the risk awareness and preventing fire-related injuries through media information on fire accidents of EB, we will conduct further analyses in Sections 4.3.1 and 4.3.2 based on the second round of survey collected data. We will examine whether the perceived importance of battery safety to injuries of EB users and people living in the neighbourhood related to fire incidents changes with or without media information. This will be approached from two perspectives: descriptive analysis and comparative analysis of the weights.

1) Descriptive analysis of results with guidance for preventing fire-related injuries

An additional set of comparative analyses was undertaken. These analyses centred on the EB fire accident and the related injuries as a focal point to ascertain whether user needs could be influenced by media news information. In the subsequent survey, participants were presented with videos concerning EB battery safety and fire-related injuries. The objective was to assess whether the video concerning EB battery safety and fire-related injuries in these presentations might impact the prioritisation of user needs.

We focused on observing the shift in the percentage of respondents who regarded "battery and charging" – a user need crucially related to preventing fire-related injuries – as "absolutely important" compared to other user needs, before and after viewing videos on fire-related injuries of EB. As illustrated in *Figure 6*, a greater number of respondents deemed "battery and charging" to be of high importance in comparison to other user needs. Here, AI(1) represents the number of respondents who deemed "battery and charging" as "absolutely important" in the first round of the survey, while AI(2) indicates the number of respondents who considered "battery and charging" as "absolutely important" under the influence of viewing the video related to fire-related injuries in the second round of the survey, respectively. This observation suggests that the proposed guidance, specifically encouraging users to view a video on injuries caused by fires in EB, may have prompted respondents to reassess and modify their evaluation of the importance of various safety indicators.

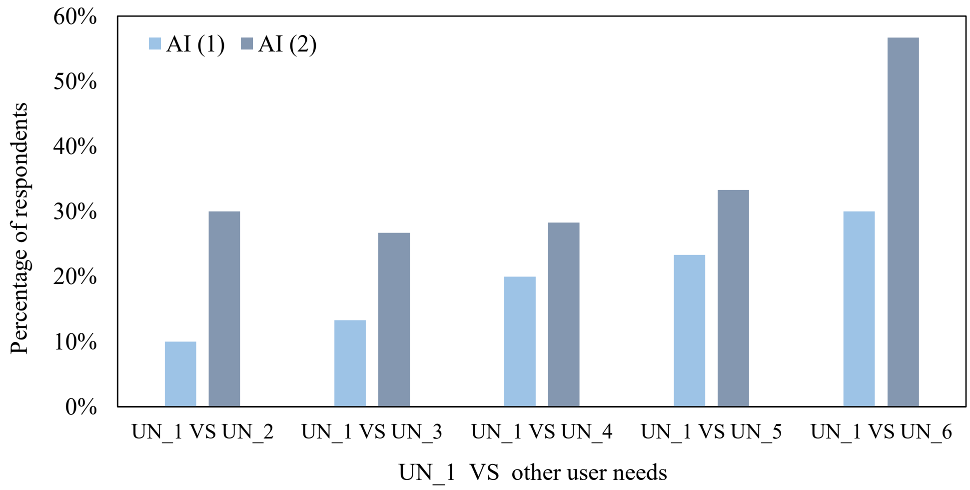

Figure 6 – Percentage of respondents who consider UN_1 more important than other user needs

As depicted in *Figure 6*, there was a noticeable increase in the level of concern about the battery and charging safety of EB following the viewing of the videos. This change is likely due to the anxiety triggered by the video content, prompting respondents to assign greater importance to safety issues for preventing injuries. The combination of visual and auditory makes information more concrete and immediate. It tends to attract more attention and evoke emotions, which may heighten users' perceptions of potential risks associated with EBs. In addition, vivid accident scenes in videos are more readily encoded and retrieved. When evaluating risk or making judgments, respondents are more likely to recall related cases. Consequently, they assign greater weight to needs closely linked to accidents, such as batteries and charging. Moreover, this increased focus on safety concerns regarding EB also impacted the respondents' answers to related questions.

2) Comparative analysis of weights with and without guidance for preventing fire-related injuries

To perform a comparative analysis of the weights with and without guidance for preventing fire-related injuries, we first calculated the weights from the second round, which were collected after participants viewed a video on fire-related injuries due to EB fire accidents. This calculation followed the methodology outlined in Section 3.2.3. We calculated the consistency ratio (CR) for each respondent following *Equation (7)* in Section 3.2.2. and used CR ≤ 0.1 as the threshold for valid samples. After the video, we collected 300 questionnaires; 273 samples passed the consistency check and were included in the analysis. The interval value and the crisp value of the relative importance weights and priority order of six user needs under the guidance framework for preventing fire-related injuries, namely, after viewing the video, are presented in *Table 4* and *Figure 7*.

The results indicate that the importance and priority ranking of user needs are similar to the initial survey, namely UN_1 ≻ UN_3 ≻ UN_2 ≻ UN_5 ≻ UN_4 ≻ UN_6.

Table 4 – Weight and priority order of six user needs after viewing the video

User needs	**UN_1**	**UN_2**	**UN_3**
Interval value	[0.294,0.313]	[0.146,0.171]	[0.164,0.186]
Crisp value	0.304	0.159	0.175
Priority ordering	1	3	2
User needs	UN_4	UN_5	UN_6
Interval value	[0.125,0.144]	[0.124,0.149]	[0.087,0.099]
Crisp value	0.135	0.137	0.093
Priority ordering	5	4	6

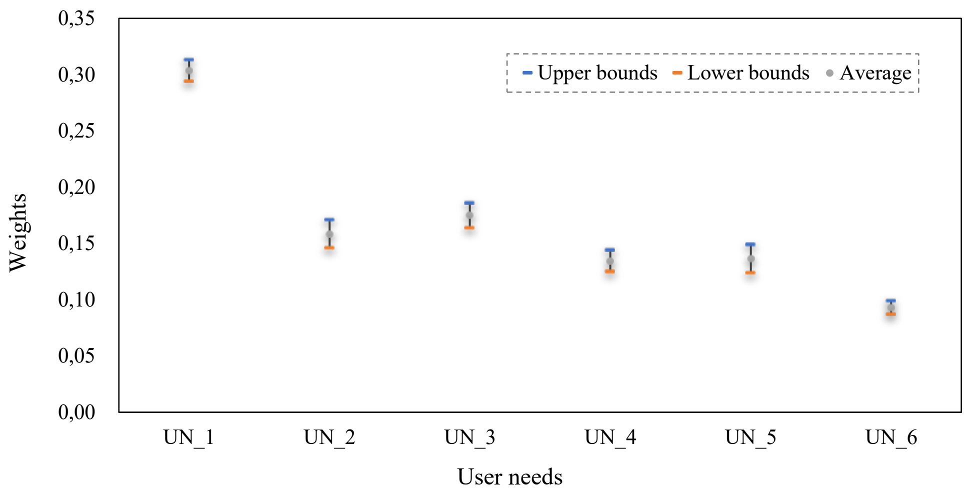

Figure 7 – Importance weights of user needs after viewing the video

By analysing the weights under the guidance for preventing fire-related injuries as per the second round survey data presented in *Table 4* and comparing them with the weights obtained without the accident-induced anxiety according to the first round survey data shown in *Table 4*, it is observed that while the priority of each user's needs remains consistent, their weight values experienced a shift. Notably, the importance attributed to "battery and charging (UN_1)" was significantly highlighted under the guidance for preventing fire-related injuries, with its average weight increasing from 0.238 to 0.304, an increase of 27.73%, with the implementation of the guidance framework discussed in Section 3.3. The guidance heightened users' focus on the safety aspects of EB with particular emphasis on user needs concerning "battery and charging". Inferior battery quality or improper charging practices could lead to injuries or even pose a threat to life. This phenomenon not only corroborates the impact of theoretical anxiety on decision-making preferences but also offers valuable insights for the practical design of products.

In addition, we used a paired sample *t*-test to evaluate the differences in the relative importance weights of six categories of user needs, namely battery and charging (UN_1), handling performance (UN_2), safety and security (UN_3), comfort and convenience (UN_4), technology and connectivity (UN_5), appearance design (UN_6), before and after video intervention. The results are shown in *Table 5*.

Table 5 – Paired-sample t-test results

User need	Item	Mean	Std. error	Pairing difference		*t*	*p value*
				Mean	Std. error		
Battery and charging (UN_1)	pre-intervention	0.238	0.061	-0.066	0.025	-2.638	0.014
	post- intervention	0.304	0.072				
Handling performance (UN_2)	pre-intervention	0.174	0.057	0.016	0.020	0.792	0.436
	post- intervention	0.158	0.045				
Safety and security (UN_3)	pre-intervention	0.218	0.065	0.043	0.022	2.008	0.055
	post- intervention	0.175	0.047				
Comfort and convenience (UN_4)	pre-intervention	0.144	0.057	0.010	0.018	0.529	0.601
	post- intervention	0.134	0.037				
Technology and connectivity (UN_5)	pre-intervention	0.147	0.049	0.011	0.019	0.562	0.579
	post- intervention	0.136	0.050				
Appearance design (UN_6)	pre-intervention	0.079	0.027	-0.014	0.011	-1.218	0.234
	post- intervention	0.093	0.032				

*Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.*

As shown in *Table 5*, "battery and charging (UN_1)" exhibits a statistically significant difference before and after the video intervention ($p = 0.014$), whereas the other categories do not reach significance. This finding aligns with the design of the intervention, which specifically emphasised fire safety associated with battery and charging systems. The selective significance observed here indicates that the video effectively guided users' attention toward the targeted safety attribute without causing random shifts in unrelated dimensions. Therefore, the results demonstrate both the directional validity and robustness of the intervention's behavioural impact.

Implications for preventing fire-related injuries

This finding, presented in Section 4.3.1, suggests that viewing videos on fire-related injuries associated with EB could increase consumer awareness of battery safety, subsequently encouraging more users to choose products with enhanced battery safety features. This short-term behavioural shift demonstrates the feasibility of using visual information as an intervention tool for risk communication. Consequently, manufacturers may allocate more resources or invest additional costs into improving battery safety components during the design process. This positive feedback loop between users and manufacturers is likely to help prevent injuries related to fire incidents. Although the present study verifies the short-term effectiveness of the video intervention, future longitudinal research is needed to examine whether these behavioural effects can be sustained over time.

This evidence provides critical insights for various stakeholders, indicating strategic opportunities for operational schemes and policymaking. For example, government agencies could consider utilising public communication channels, such as community digital screens or subway corridors. Through these channels, short videos or news segments related to EB fire incidents could be broadcast to enhance public awareness of EB-related fire risks and encourage safer consumer behaviour [80]. In turn, this would help prevent fire-related injuries associated with EB. In addition, government agencies or e-commerce platforms could draw on promotional strategies, such as the digital coupon programs launched by the Chinese government on platforms like Yunshanfu, a user's UnionPay App [81]. By collaborating with short-video platforms like Douyin, they could implement conditional incentive mechanisms. For instance, users might be required to watch an EB safety education video of about 100 seconds in length. Upon completion, they could receive a discount coupon worth 50 or 100 RMB for purchasing EB products. Other methods are also explored to motivate consumers to watch the video before purchasing or using EB. The funding for these coupons could come from the government to encourage consumption or from EB retailers for marketing purposes.

Although the long-term impact of such interventions requires further validation, short-term effects are clearly observable. When users directly watch a safety video before purchase and immediately receive a discount coupon, the intervention can effectively guide their attention toward safety attributes and influence their purchase decisions. This paper primarily discusses the rationale and feasibility of this guidance framework, proposing the specific operational details as a topic for future research. Then we could leverage this dynamic by emphasising the safety features of their products' batteries and concurrently displaying videos on fire-related injuries. This strategy may pivot consumer focus towards battery safety considerations, elevating battery quality above the basic safety standards. By doing so, this approach could reduce the number of potentially hazardous batteries at the source, thus helping to prevent fire-related injuries from the root cause.

In addition, for the older battery-powered EB already in use for a few years, while a subsidised recycling approach can mitigate their hazards, financial constraints on government spending necessitate alternative strategies. Broadcasting the potential risks associated with EB with older batteries through policy directives could encourage more people to retire these old EB. This approach not only reduces the higher risks of fire-related injuries associated with older batteries in EB but also has an added benefit; the EB of the newer standard of battery is more environmentally friendly. Transitioning to these newer models not only may prevent fire-related injuries but also benefits the environment.

5. CONCLUSION

This paper presents a structured user-centred approach to promoting EB adoption and mitigating fire-related risks, focusing on the prioritisation of user needs related to safety. Drawing on comparative survey data collected in two rounds, the study yields the following conclusions.

1) We identified and prioritised six categories of user needs. The analysis consistently revealed a clear hierarchy, with "battery and charging" (UN_1) and "safety and security" (UN_3) emerging as top priorities, followed by "handling performance" (UN_2), "technology and connectivity" (UN_5), "comfort and convenience" (UN_4) and "appearance design" (UN_6). These findings offer practical guidance for manufacturers to optimise product design and resource allocation.
2) We further validated the feasibility of guiding user priorities through video-based information interventions. A comparative analysis between two survey rounds shows that the weight of "battery and charging" (UN_1) increased from 0.238 to 0.304 (a 27.73% rise) after viewing the fire-safety video, and "battery and charging (UN_1)" exhibits a statistically significant difference before and after the intervention ($p = 0.014$). This targeted and statistically significant change confirms the effectiveness of the intervention in heightening users' awareness of battery safety. The results thus provide empirical evidence of short-term behavioural responsiveness to safety information, consistent with the intended focus of the video content.

While this study provides meaningful insights, several aspects warrant further exploration. Although the research sample is primarily drawn from Chinese college students, which may limit the generalisability of the findings, the proposed three-phase framework offers a transferable methodological approach that can be adapted to different countries or regions to explore context-specific user needs and safety issues in EB development. Future research could broaden the sample to include participants from diverse cultural and policy environments, thereby enabling cross-cultural validation and refinement of the framework. Second, EB users and non-users are examined collectively, without distinguishing potential intergroup heterogeneity; future studies could compare these groups to reveal differences in perceptions and behaviours. Third, the evaluation of the video intervention emphasises short-term outcomes, leaving its long-term impact less understood; longitudinal research designs would therefore be valuable to assess the sustainability of such interventions in shaping user cognition and priorities. In addition, future work could diversify research methods, incorporating experimental designs, qualitative approaches (e.g. interviews or focus groups), or observational studies based on actual purchasing behaviour to enrich the findings. Fourth, the current evaluation focuses on short-term outcomes, leaving the long-term impact less understood; longitudinal studies would therefore be valuable for assessing the durability of intervention effects on user cognition and priorities. In addition, future work could diversify research methods by incorporating experimental, qualitative (e.g. interviews or focus groups), or behavioural observational approaches to provide a more comprehensive understanding of user decision-making.

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APPENDIX A. Survey on the importance of demand indicators for electric bicycles

1. Your gender:
A: Male
B: Female

Electric bicycle demand indicators are summarised in six categories
(1) Battery and charging
(2) Handling performance
(3) Safety and security
(4) Comfort and convenience
(5) Technology and connectivity
(6) Appearance design
Among them, according to this research method, battery and charging and appearance design are selected as two indicators as “reference points”.

3. According to your preferences, how important is battery and charging relative to handling performance?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

4. According to your preferences, how important is battery and charging relative to safety and security?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

5. According to your preferences, how important is battery and charging relative to comfort and convenience?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

6. According to your preferences, how important is battery and charging relative to technology and connectivity?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

7. According to your preferences, how important is battery and charging relative to the appearance design?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

8. According to your preferences, how important is handling performance relative to appearance design?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

9. According to your preferences, how important is safety and security relative to appearance design?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

10. According to your preferences, how important is comfort and convenience relative to appearance design?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

11. According to your preferences, how important is technology and connectivity relative to appearance design?
(A) Absolutely important
(B) Very important
(C) Moderately important
(D) Weakly important
(E) Equally important

APPENDIX B.

The outcomes of these comparisons, as submitted by an individual respondent, are presented in *Table 1*.

Table 1 – Sample of reference comparison with language terms

Criteria	c_1	c_2	c_3	c_4	c_5	c_6
Best (c_1) to others	EI	EI	WI	EI	WI	AI
Others to worst (c_6)	AI	AI	AI	MI	EI	EI

Using the transformation rules in *Table 1* between language terms and TFNs, we can determine the fuzzy best-to-others vector and fuzzy others-to-worst vector.

$$\widetilde{A}_B = [(1,1,1),(1,1,1),(2/3,1,3/2),(1,1,1),(2/3,1,3/2),(7/2,4,9/2)] \quad (1)$$

$$\widetilde{A}_W = [(7/2,4,9/2),(7/2,4,9/2),(7/2,4,9/2),(3/2,2,5/2),(1,1,1),(1,1,1)]^T \quad (2)$$

We transform fuzzy best-to-others vectors, *Equation (1)* and fuzzy best-to-others vectors, *Equation (2),* into comparison vectors, as shown in *Equations (3)* and *(4)*.

$$\overline{A}_B = \{[1,1],[1,1],[5/6,5/4],[1,1],[5/6,5/4],[15/4,17/4]\} \quad (3)$$

$$\overline{A}_W = \{[15/4,17/4],[15/4,17/4],[15/4,17/4],[7/4,9/4],[1,1],[1,1]\}^T \quad (4)$$