J Inf Process Syst, Vol.19, No.2, pp.219~231, April 2023
https://doi.org/10.3745/JIPS.04.0271

ISSN 1976-913X (Print)
ISSN 2092-805X (Electronic)

JOURNAL OF INFORMATION PROCESSING SYSTEMS JIPS

Research and Design of Functional Requirements of Shared Electric Bicycle App Based on User Experience

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Abstract
Intelligent applications are crucial for increasing the popularity of shared urban electric bicycles (EBs). Building an application platform architectural system that can satisfy independent user operations is critical for increasing the intelligent usage of shared EBs. Consequently, we collected online reviews of shared EB applications, conducted semantic processing and sentiment analysis, and refined the positive and negative review data for each function. The positive and negative review indices of each function were calculated using the formulae for positive and negative review indices of product functions, thereby determining the functions that need to be improved. Each function of the Shared EB application was improved according to its business process. The main contributions of this study are to build a user requirement architecture system for the Shared EB application with five dimensions and 22 functions using the Delphi method to design the user interface (UI) of this application based on user satisfaction evaluation results; to create a high-fidelity dynamic interaction prototype and compare user satisfaction before and after improving the Shared EB application functions. The testing results indicate that the changes in the UI significantly improve the user experience satisfaction of the urban Shared EB application, with the positive experience index increasing by 69.21% and the negative experience index decreasing by 75.85% overall. This information can be directly used by relevant companies to improve the functions of the Shared EB application.

Keywords
Dynamic Interaction Prototype, Functional Requirements, Online Comments, Shared Electric Bicycle (EB), User Interface (UI), User Satisfaction

1. Introduction

Urban shared electric bicycles (EBs) have quickly become one of the most popular modes of transportation for city dwellers, enabling increased convenience for short-distance travel, work, and shopping in everyday life. However, as the demand for urban shared EBs grows, so does the demand for improvements in shared EB apps. Some problems associated with using traditional shared EBs, such as insufficient intelligence, inconvenient vehicle returns, and obfuscated pricing computations, have adversely affected the experience of using urban shared EBs. Previous researchers have addressed these issues; however, their recommendations have primarily focused on enhancing the physical amenities of shared EBs. These measures can only improve the convenience of shared EB use in local areas and cannot address the need for the intelligent use of the Shared EB application (app). For example, users can operate

Manuscript received April 28,2022; first revision July 7, 2022; accepted August 10, 2022.
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and set certain functions quickly and flexibly by using the Shared EB app interface. As a result, our study focuses on improving the interface system of the Shared EB app to suit users' expectations of intelligent and autonomous operations. Using positive and negative user review indices, we evaluated 22 functional requirements of the Shared EB app in five dimensions, which revealed that several functions require urgent improvement in the current urban Shared EB app based on three elements of user experience: functional features, usage scenarios, and user feelings. A user interface was designed for the Shared EB app, and dynamic interaction prototypes were created using the AXURE 9.0 software. Functional ease-of-use tests were conducted on the Shared EB app's high-fidelity prototype, which increased user satisfaction with each function and significantly increased the efficiency and success rate of product creation.

2. Literature Review

Research on shared EBs has focused on the sustainability and practicality of shared transportation and the practicality, as well as differences in the adoption of shared EBs worldwide. For example, Ahmadi Nozari et al. [1] used the fuzzy Delphi approach to identify the variables influencing the sustainability of shared transportation and recommended solutions to increase its convenience. Todd et al. [2] compared the conditions for deploying shared EB systems across continents, explicitly analyzing the characteristics of each region, thereby providing different regions with a reference and basis for establishing shared EB systems. In developing countries such as India, urban infrastructure and travel characteristics are the biggest obstacles to implementing shared EB systems [3].

The recent literature from China concerning this domain concentrates on three aspects. The first is the long-term development of intelligent shared transportation in China. For example, Beijing's current environmental and carbon emission restrictions provide favorable external conditions for the sustainable development of shared transportation [4,5]. According to Liang et al. [6], it is possible to support the growth of shared electric transportation by increasing the user perception of the green value of shared EB systems, which encourages development and increases the sustainability of shared transportation, boosts trust in green transportation, and encourages green travel loyalty. Furthermore, the complementary benefits of shared EBs and public transportation (e.g., subways, buses, and cabs), which include substitutability for household electric vehicles and private cars, generate a positive effect on the sustainable development of shared transportation in China [7,8].

The second aspect is the investigation of the operation and management of shared-transportation mobile applications. For example, Zhang [9] presented a unified interactive visual interface to improve historical data exploration and traffic forecasting. The visual design of bright application icons affects the user experience; it is also significantly impacted by unified application icons. Critical parts of the application are presented in the graphic UI [10,11].

The third aspect is the design and development of shared transportation systems based on user requirement analysis. Zhou et al. [12] considered requirement analysis essential for developing intelligent products and proposed a requirement analysis framework for user experience-oriented innovative services. In practice, however, some intelligent systems for shared transportation are not widely used. One important reason is the insufficient assessment of changes in user needs, as stated by Wang et al. [13]

and Kwon [14]; they proposed a context-aware concept assessment method for the design iteration of intelligent product-service systems to update the system in time to meet user needs.

According to the above analysis, prior studies on shared transportation have concentrated more on the sustainability of green shared transportation [15,16], whereas theoretical research on shared transportation mobile applications is still in its infancy. With the advances in information technology, people have begun to rely on intelligent applications for shared transportation [17]. At the theoretical level, a more significant functional analysis of shared-transportation mobile apps based on user needs is required to guide the improvement of shared intelligent transportation mobile application systems [18]. As a result, we use information from positive and negative reviews of existing shared EB mobile applications to identify the functions to be improved, test their effectiveness after improvement, and explore the improvement of shared intelligent transportation sustainability based on previous literature.

3. Analysis of the User Experience with the Shared EB App

As technology continues to develop and people's daily needs continue to grow, the immediacy and timeliness of Internet products lead to an essential difference between their updates and iteration speeds compared to those of traditional products. The development of technology and the changing needs of users, coupled with an emphasis on the user experience of Internet products, has prompted the continuous exploration and optimization of various functions based on user opinions and suggestions. This study utilizes user feedback from an existing shared EB application to make targeted adjustments and enhancements to improve user satisfaction with shared e-bikes.

3.1 Positive and Negative Review Information Collection of Shared EB App

Five user experience forums concerning shared EBs in the "BAIDU" Post and China's "ZHIHU" were chosen as information sources to obtain user review data regarding shared EB usage experience. Online reviews of the Shared EB app web-system comprise many subjective remarks from users regarding items and services. Web crawlers were used to collect user reviews of the Shared EB mobile application systems. These data were then imported into the GOSEEKER text collection and sentiment analysis system, automatically splitting words and refining keywords without additional operations. These keywords reflected the topics in the comments. The nature and frequency of all refined words were then matched using a sentiment lexicon that can freely add relevant sentiment words, remove irrelevant sentiment words, or reset sentiment words to identify positive, negative, and double negative-positive words in the comments. Positive terms include “good,” “smooth,” and “convenient,” among others, whereas negative terms include “difficult,” “terrible,” and “disappointing,” among others. Some reviews lacked apparent positive and negative sentiment words, such as “one-click charging function is too excellent” and “one-click repair is too long”; even though both reviews contain the word “too,” the former belongs to the positive evaluation group and the latter to the negative evaluation group. This situation necessitated exporting the word segmentation results.

Subsequently, keywords relevant to the functions of the Shared EB mobile application system were selected more precisely by manual word selection, which compensates for the deficiencies created by the imprecision of automatic keyword refinement. Finally, to revise the review texts using sentiment analysis, the positive and negative evaluation statistics of partial essential functions were intercepted, as illustrated in Fig. 1. It should be noted that when collecting product evaluations, the users' experiences of the functional features in various scenarios must be sorted out. User experiences incorporate three aspects: functional features, usage scenarios, and user emotion. As determined by statistical analyses, 95.7% of comments concerned “user emotion,” 88.7% concerned “functional features,” and 75.4% concerned “use scenarios.” Generally, the functional features of Shared EB app systems in various usage scenarios contain both positive and negative comments. Systematic analysis of the impact of these functional features with two-way comment information on user experience was considered when designing product function optimization solutions to guide developers in understanding the strengths and weaknesses of Shared EB app systems and promoting product upgrades.

1	Function	Scenario		User Emotion	Quantity
128	Shared electric bicycle failure	On the way	postive	convenience、succinct、not bad、	12
129	One-click repair	After failure	negative	slow、too long、not good	39
130	Balance refund	Refund process	postive	convenience、nice、Excellent	33
131			negative	Complicated、inconvenience、di	139
132	One-click location	Check vehicle locati	postive	not bad、convenient	21
133			negative	delay、Inaccuracy、mistake、slc	152
134	amount of payment	Payment process	postive	convenience、not bad	75
135			negative	too few、Unreasonable,Disappoi	8
136	Return reward	Return	postive	nice、convenience	24
137			negative	too slow、too long、Complicatec	56
138	Overall function	End of trip	postive	Smooth、Complete	58
139			negative	too less、Unreasonable、too mai	196

Fig. 1. Screenshot of some results of user comment analysis regarding the existing shared EB application.

3.2 Influence of Functional Features and Usage Scenarios of the Shared EB App on User Satisfaction

To improve the Shared EB app system, this study analyzed the impact of the functional features and usage scenarios of this app on user experience by integrating positive and negative user comments. The analysis was conducted in two dimensions. The first was to analyze the functional features that significantly impact users' feelings from the perspective of product functionalities. The second was to analyze the usage scenarios that significantly impact users' feelings from the perspective of use cases. It is worth noting that some of the functional features of the Shared EB app received both positive and negative responses. However, simply counting the number of positive or negative comments cannot objectively reflect users' overall satisfaction with a product. Therefore, when analyzing the influence of these features with two-way review information on user satisfaction, the number and proportion of positive and negative reviews must be calculated to objectively reflect user satisfaction with these product features. Taking the product characteristic T as an example, let us suppose that the number of positive comments is P_T and the number of negative comments is N_T, where α and β are the weights of positive and negative reviews, respectively. Among all product features, the product characteristic with the most positive comments is A, and the corresponding number of positive comments is P_A. The product characteristic with the most negative comments is B, which corresponds to the number of negative comments N_B. Thus, the positive experience index of product characteristic T is expressed as,

$$I_{P_T} = \alpha \times \frac{P_T}{P_A} + \beta \times \frac{P_T}{N_T+P_T} \quad \alpha,\beta = [0\ 1], \alpha+\beta = 1, \tag{1}$$

whereas the negative experience index is,

$$I_{N_T} = \alpha \times \frac{N_T}{N_B} + \beta \times \frac{N_T}{N_T+P_T} \quad \alpha,\beta = [0\ 1], \alpha+\beta = 1. \tag{2}$$

We conducted a brainstorming session with 12 employees, three Internet product managers, five system development programmers, and 20 college students to ask them about the Shared EB app's functional requirements to scientifically and reasonably realize the app's functional requirements architecture. The functional architectural system of the Shared EB app was then divided based on an analysis of user review data and real usage experiences; experts were invited to propose the types of functions using the Delphi method. After repeatedly splitting and integrating these features, a shared EB app system architecture was constructed. Table 1 shows the five categories for 22 functional features: the scanning code function, wallet function, one-click convenience function, reward function, and personal center.

Table 1. Experience index and number of comments on the functional features of the Shared EB app

Dimension	Functional features	Experience index		Number of occurrences
		Positive (I_{P_T})	Negative (I_{N_T})	
Code scanning function	Bicycle scanning code	0.78	0.12	36
	Return the bicycle with the code	0.32	0.75	8
Wallet function	Billing top-up	0.54	0.69	105
	Payment method	0.88	0.1	45
	Balance inquiry	0.3	0.67	123
	Deposit return	0.32	0.76	172
	Automatic top-up	0.64	0.21	17
	Auto-deduction	0.30	0.56	32
	Fee breakdown	0.21	0.46	5
One-click convenience function	Electric quantity alarm	0.24	0.72	128
	One-touch charging	0.67	0.56	23
	One-click repair	0.21	0.56	28
	One-touch alarm	0.84	0.32	19
	One-click search	0.1	0.56	5
	One-click location	0.32	0.76	128
	Map	0.2	0.76	93
Reward function	Homing bonus	0.75	0.23	15
	Credit score	0.78	0.24	36
Personal center	My itinerary	0.32	0.77	77
	Change password	0.27	0.71	9
	Instructions for use	0.12	0.89	5
	Feedback	0.14	0.37	15

The positive and negative experience indices of the 22 functional demands of the Shared EB app were calculated using formulas (1) and (2), whereby the number of times each function appeared was counted. Based on this, the impact of the functional features and usage scenarios of shared EBs on user satisfaction were examined. In general, for functional product features that have a more significant impact on customer satisfaction, the positive and negative experience indices were higher. The results are summarized in Table 1.

As shown in the calculation results in Table 1, some functional features do not receive much attention, such as "one-click search" and "instructions for use," with high negative comment indices of 0.76 and 0.89, respectively. There are few comments regarding these characteristics, which means that they have little impact on user satisfaction and can be ignored for the time being to save product development costs.

3.3 Shared EB App Function Enhancement

When improving and upgrading the Shared EB app, the focus should be on improving the functional features with high negative experience indices and upgrading the product features with high positive experience indices. It should be noted that if the positive and negative experience indices of a particular characteristic (e.g., billing and recharging) are large, this indicates that this characteristic has a more significant impact on user satisfaction, and the users' evaluation of the characteristic is polarized. Therefore, when improving this characteristic, the differences in user needs should be considered, and personalized solutions must be created to facilitate user choices according to their needs to improve user satisfaction. Table 2 lists the functional needs to be addressed as well as the causes and consequences of improvements in the Shared EB app.

Table 2. Functional features of the Shared EB app to be improved

Functional features to be improved	Causes and effects
Billing top-up	Reason: There are many comments about the billing recharge method, and the proportion of positive and negative comments is high. Improvement: Change the single-time billing method for billing recharge, and add half-day and full-day billing methods.
Balance inquiry	Reason: Some users reported delays in chargeback and that they could not view the balance in real-time. Improvement: Add real-time chargeback for balance inquiry to ensure balance and chargeback synchronization.
Balance return	Reason: Complaints about the speed of balance return. Improvement: Shorten the return time of the balance and change it to instant arrival.
Deposit return	Reason: Complaints about the speed of deposit return. Improvements: Shorten the time for the deposit to be returned as-is and change it to instant.
Auto-deduction	Reason: Comments discussing a preliminary deposit indicate that automatic deduction cannot be bound to other payment methods. Improvements: Add an automatic balance deduction reminder function to bind an "ALIPAY" or "WeChat" payment when the balance is insufficient.
One-click repair	Reason: Users indicated that the one-click repair function is too general and not sufficiently detailed. Improvement: Add a category of one-click repair options for users to choose from.
Electric quantity alarm	Reason: Users believe that the power warning is not apparent, making the EB run out of power before the user can complete the trip. Improvement: After adding the scan code, the power warning interface automatically appears.
One-click location	Reason: Some users reported that the one-click positioning is sometimes inaccurate. Improvements: Improve the positioning function to locate the EB used in real-time.
My trips	Reason: Users reported that viewing the trip and deduction details was inconvenient. Improvements: Add real-time trip and deduction details to the personal center for users.
Map	Reason: Some users think the map's location markings are unclear. Improvements: Drop the 2D flat map and enable 3D rotation and the current city-building simulation map.

4. Transformation of Shared EB App for Prototype Design

4.1 Product Prototyping

When using a product, users frequently encounter two types of barriers: communication and assessment barriers. To establish a barrier-free interface of comprehensibility, developers should realize an interface for human-computer interaction design while translating the user needs to design. Using the AXURE 9.0 software, "user-centered" product prototyping may create a reasonable business process model for the Shared EB app reflecting user needs. The software can efficiently and quickly create system prototypes, use test data to visually create interfaces for interactive and demonstration functions, and help developers organize the entire business process of the app. Moreover, it helps users complete accurate requirements analysis, thereby significantly increasing the effectiveness and success rate of product development.

4.2 Low-Fidelity Prototype of the Unified Modeling Language (UML) Time Sequence Flow Chart of the Shared EB App

A low-fidelity prototype transforms conceptualized ideas into simple and elegantly designed structures through sketches, storyboards, or line drawings at the beginning of product design to help research and development (R&D) personnel collect information on product requirements in the early stages of product development. Thus, design ideas should be rationalized during R&D, such as login, registration, real-name authentication, registration completion, sweep-code recharge, scan code, and the use of trip-locked-complete payment. The logical relationship between each function in the Shared EB app must be clarified to provide ideas for subsequent high-fidelity prototyping and interface design. Low-fidelity prototype diagrams exhibit transitional properties. Although the prototype may look like a "draft," it provides the design and development staff with an open imagination space, which can be added, deleted, or adjusted as needed in the later design and production to ensure the integrity of the product's logical structure, as shown in Fig. 2.

4.3 High-Fidelity Prototype of the Shared EB App

The high-fidelity prototype is similar to the finished product. It dynamically integrates the product use process, interactivity, and specific content to construct a complete product–process system based on the low-fidelity prototype. The simulation is then run using the test data to provide users with a realistic interaction experience with the product. If a product is tested after development, leading to errors being discovered and the code being overturned, a very high reset cost would be incurred. By contrast, the cost of discarding a prototype is relatively low. As a result, AXURE 9.0 and other prototyping software can quickly develop a comprehensive, high-fidelity product-dynamic-interaction prototype to test whether the product flow is smooth, the improved functions are reasonable, user satisfaction measurement results are improved, and so on. It is convenient to find bugs and save time and money. During the high-fidelity prototype testing stage, developers can refine user feedback over time and iterate until they achieve a satisfactory outcome before proceeding to the next formal product development stage.

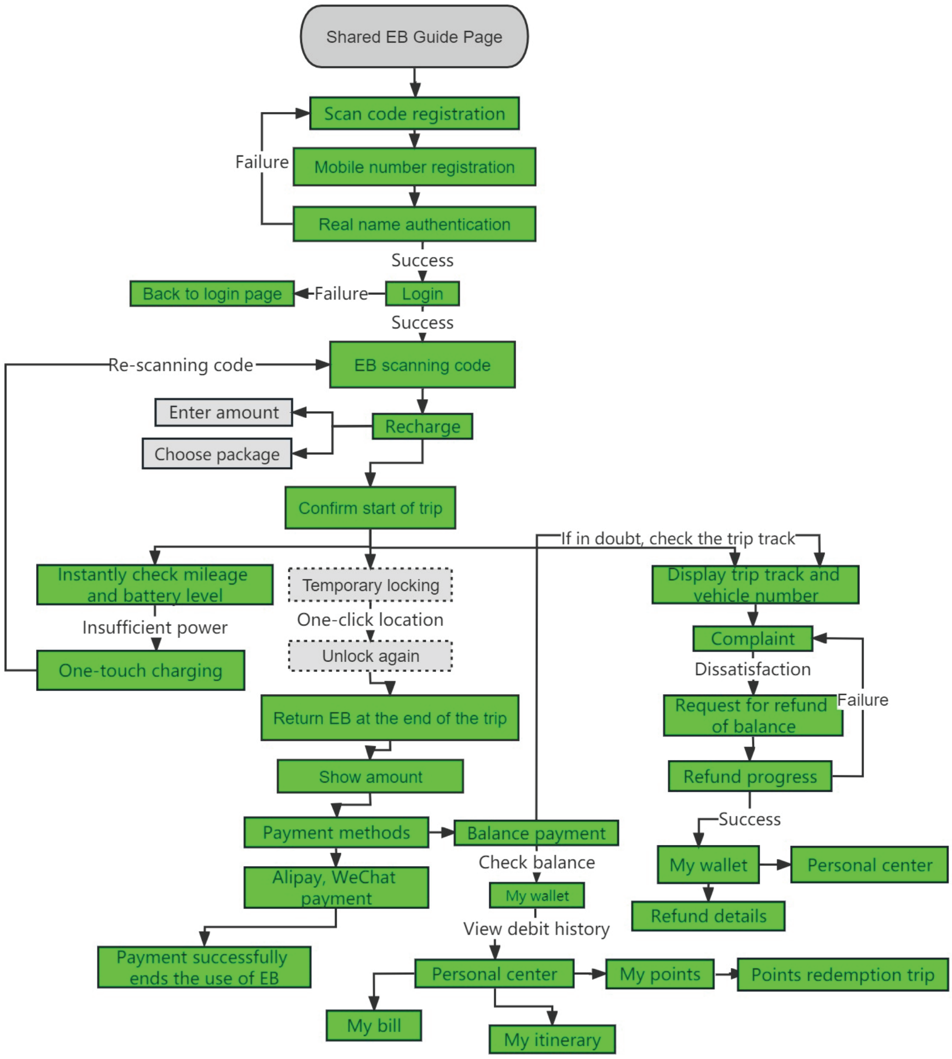

Fig. 2. UML time sequence flowchart of the Shared EB app.

- With the latest version of AXURE, a high-fidelity prototype visual design page can be used directly for product development, thereby saving time and money. Consider, for example, the map display of a shared EB. In general, shared mobile transportation applications use 2D flat maps. However, to help users reach their destinations more accurately and quickly, the upgraded app uses 3D maps with view effects provided by vector map data, thereby increasing map functions such as rotation and perspective tilt compared to 2D maps. Moreover, they increase smoothness while ensuring levelless zoom and other features, making it convenient for users to swiftly reach their destinations while also enabling them to review the details of their trips and deductions, as shown in Fig. 3.
- All interfaces of the Shared EB app dynamically interact according to the operation process using AXURE 9.0, which is a product prototype tool offering users a real operating experience without programming. A visual working environment is employed to ensure the immediate demonstration of the product. For example, simulation data are used for the payment function of the Shared EB

app to ensure that the functions of registration, login, top-up, trip, and payment are smoothly handled. These prototypes provide a clear functional logic relationship for front-end development and ensure product usability. As shown in Fig. 4, once the code is successfully scanned, the journey begins, and trip parameters are displayed on a 3D map. After the business process creates the prototype of the Shared EB app, the prototype can be shared to obtain the sharing link and QR code and can be visited by clicking the link or scanning the QR code on a mobile phone.

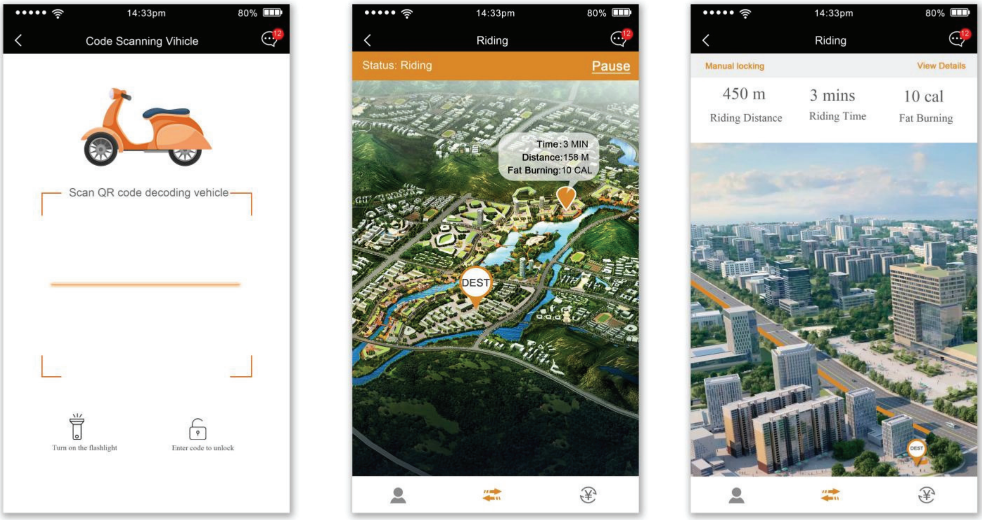

Fig. 3. High-fidelity prototype for the Shared EB app.

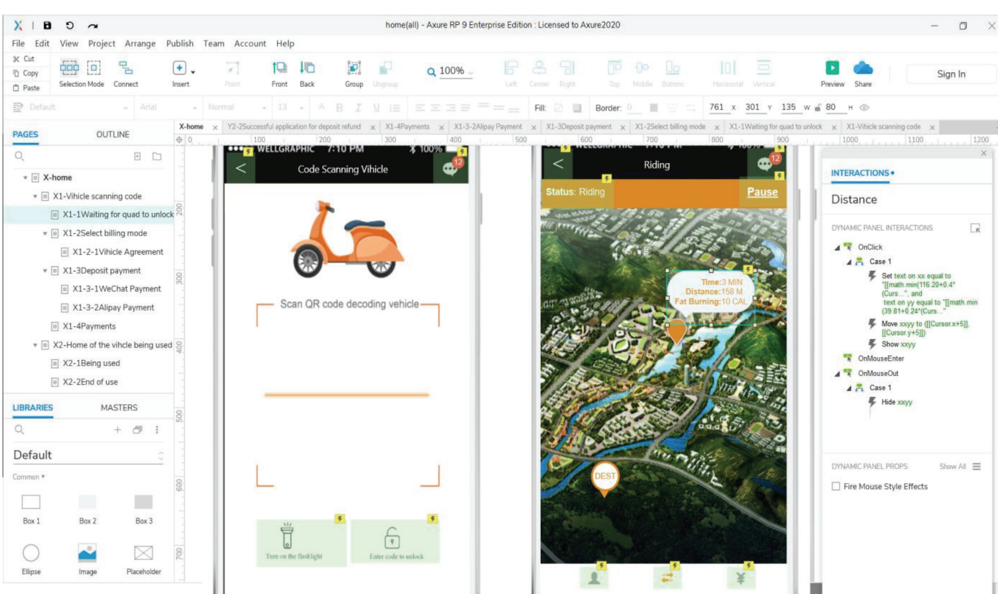

Fig. 4. Part of the interface prototype and dynamic interaction for the Shared EB app generated using AXURE 9.0.

5. Comparison of User Satisfaction before and after Optimization

The exported product demo package was tested for usability after the completion of the Shared EB app prototype. To determine whether there was a significant change in user satisfaction, we continued to use the five shared EB user experience forums as the information source. We deployed the improved Shared EB app demo package in the forums, instructing users to follow the Shared EB app business process shown in Fig. 2 for system testing.

Following the test, we utilized an online user satisfaction questionnaire to assess the three user experience elements of the upgraded features in Table 2, which included functional features, usage scenarios, and user emotions. Then, using formulas (1) and (2), the positive and negative experience indices of the functional features were re-calculated, counting the number of times each characteristic was evaluated. These results were then compared with the positive and negative indices prior to improvement. Table 3 presents the evaluation results.

As shown in Table 3, the improved Shared EB app functions provided higher user satisfaction than before. The positive score of user evaluation improved dramatically, whereas the negative index decreased significantly. The overall positive experience score increased by 69.21%, and the negative experience index decreased by 75.85%. The number of comments also decreased dramatically, indicating that users had fewer problems with Shared EB and that the process of using it was smoother. This indicates that the improved Shared EB app function is feasible. The main reason the test passed is that this study prioritized the user experience and evaluated the users' subjective and objective evaluations of the Shared EB app functions positively or negatively based on the three elements of user experience. We optimized and improved each function based on the evaluation results, which resulted in increased user satisfaction with the Shared EB app.

Table 3. Comparison of data after the improvement of the Shared EB app function

Functional feature	Positive index improvement			Negative index improvement			Number of occurrences
	After	Before	Rate (%)	After	Before	Rate (%)	
Billing top-up	0.72	0.43	67.44	0.11	0.69	84.06	9
Balance inquiry	0.68	0.39	74.36	0.15	0.67	77.61	12
Balance return	0.69	0.41	68.29	0.05	0.76	93.42	23
Deposit return	0.84	0.48	75.00	0.16	0.56	71.43	3
Auto-deduction	0.71	0.44	61.36	0.12	0.72	83.33	26
One-click repair	0.77	0.51	50.98	0.3	0.56	46.43	8
Electric quantity alarm	0.82	0.52	57.69	0.2	0.73	72.60	19
One-click location	0.85	0.45	88.89	0.09	0.76	88.16	15
My trips	0.76	0.43	76.74	0.32	0.77	58.44	13
Map	0.69	0.39	76.92	0.14	0.57	75.44	5

6. Conclusion

Based on consultations with several experts in shared transportation, this study developed a user requirement architecture system that includes five dimensions (code scanning function, wallet function, one-click convenience function, reward functions, and personal center) and 22 sub-dimensions of shared EB user requirements. This study used web crawlers to collect user review data from the current Shared EB mobile application system. Subsequently, these data were imported into the GOSEEKER text sentiment analysis system to obtain positive and negative sentiment data for all functions of the Shared EB app. The positive and negative experience index formulas were used to calculate user satisfaction, and the number of comments was counted. Ten services, including billing top-up, balance inquiry, balance return, deposit return, auto-deduction, one-click repair, electric quantity alarm, one-click location, my trips, and maps, were observed to require urgent improvement. Subsequently, using the AXURE 9.0 software, a high-fidelity prototype flowchart of the Shared EB app and thorough and instructive flowchart for testing it were created. The improved Shared EB app functions were observed to considerably boost user satisfaction.

This study provides a reference for the design and development, and optimization of related mobile applications by identifying the various needs of users with respect to Shared EB apps. The shortcomings of this study are as follows: (1) the sentiment analysis of user comments in the Shared EB mobile application system was coarse-grained; there was no fine-grained identification of implicit sentiments or implicit evaluation objects within user comments. The richness of semantic expressions may cause errors in lexical matching. In subsequent research, comments that do not involve positive or negative worrisome words will be subjected to fine-grained sentiment analysis. (2) Without integrating with a real-world cycling situation, this study tested the business process and the functioning of each function of the Shared EB app using simulation data. In future research, we will continue to improve the quality of each function and collaborate with Shared EB firms to test user satisfaction with the upgraded Shared EB app during actual usage. New technologies and shared transportation demands will also be monitored in real time to improve the comfort and ease of use of the Shared EB app.

Acknowledgement

This work was supported by the Major Project of Philosophy and Social Science Fund of Universities in Jiangsu Province (2021SJZDA031).

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