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EVALUATING USER INTERFACE REQUIREMENTS FOR BEIDOU-BASED CONSUMER MAP NAVIGATION APPLICATIONS IN CHINA

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Abstract
BeiDou-based consumer map navigation applications are increasingly important for daily mobility in China, supporting route planning, real-time location services, and travel decision-making in both urban and rural environments. Although existing studies have widely examined the technical performance, positioning accuracy, and service development of the BeiDou Navigation Satellite System (BDS), comparatively less attention has been given to the user interface requirements that shape user experience, usability, trust, and adoption. To address this gap, this paper presents a conceptual framework for evaluating user interface requirements in BeiDou-based consumer map navigation applications. The study organizes UI requirements into four major categories: functional, visual, interaction, and adaptive requirements. These categories cover essential interface elements such as destination search, route guidance, map clarity, icon visibility, menu organization, alert notifications, personalization, and context-aware adaptation. The proposed framework integrates requirement identification, user-centered assessment, expert feedback, statistical analysis, and multi-criteria prioritization methods, including AHP, ANP, and Fuzzy ANP. It also introduces simulation-based and graphical representations to demonstrate how interface requirements can be analyzed, ranked, and refined in future empirical studies. By linking BeiDou-enabled navigation services with human-computer interaction and mobile usability principles, this study provides a structured foundation for improving navigation interface design. The framework can support researchers, designers, and developers in identifying critical UI elements and producing more usable, efficient, and context-aware navigation applications. Future work will involve empirical validation through user surveys, expert evaluation, and requirement prioritization to generate practical design guidelines for diverse consumer users in China.

1. INTRODUCTION
Consumer map navigation applications have become an everyday aspect of mobility, enabling route planning, travel with traffic awareness, searching a destination, and making a decision based on the location, all on a mobile device. The significance of such applications in China is further intensified by the fact that in digital navigation platforms, daily commuting into cities, intercity travel, and location-based services ecosystems are deeply intertwined. Meanwhile, the increasing use of BeiDou Navigation Satellite System (BDS) has provided a solid technological

basis of local, high-availability navigation services that can serve the large-scale consumer applications [1], [2], [3]. With numerous studies on the accuracy of positioning, signal structure, augmentation services, and technical development of BDS, much less systematic emphasis has been given to the user interface (UI) aspect of BeiDou-based consumer map navigation apps [1], [2], [4]. However, to the average user the interface is the most direct and the most powerful component of the system as it defines the manner in which the capability of the satellite-enabled interfaces is converted into legible, useful, trustworthy interaction.

Having a highly developed navigation system does not necessarily mean that it will be a good user experience. Users do not communicate with signals, satellites, or augmentation protocols, but with menus, icons, route lines, alerts, controls and contextual guidance. This is the reason why user-centered design is requisite in the navigation applications particularly those aiming to be used by the masses. In previous studies on mobile usability, it has always been found that the success of an application hinges on effectiveness, efficiency, learnability, satisfaction, and error prevention [5], [6]. The issues are even more urgent in terms of mobile navigation, where people have to process information quickly as they walk, drive, ride a bike, or multi-task in the real world [7], [8]. Interfaces quality is therefore not just a cosmetic concern, as it has a direct impact on cognitive load, spatial knowledge, confidence in route guidance, and general user acceptance.

The discussion of mobile maps and navigation interfaces also shows that the visual elements of the interface, like the visibility of the map, the location of the buttons, the position of the icons, the interaction of zoom and pan, screen orientation, and the visual hierarchy are highly influential in determining user performance. Research on graphical user interface in digital maps indicates that the layout of the interfaces can affect user attention and interaction results [9]. Findings in literature on mobile map size and interactive interface suggest that the decisions made in terms of small screen design have a profound impact on the performance of wayfinding and spatial knowledge acquisition [10]. Correlated literature, also reveals that the attributes of map design such as simplification, symbolization, display orientation can enhance or decrease usability as task requirement demand [11]. Moreover, comparative analyses of traditional digital map interface and location-based augmented reality show that varying interface modalities have varying efficiency, engagement, and user preference balances [12]. Collectively, these studies provide evidence that the performance of navigation is very sensitive to the UI design and that there is a need to determine and organize the interface requirements that are most pertinent to consumer navigation systems.

The other crucial point is context. The nature of navigation applications is very dynamic, and interface requirements can vary depending on the nature of the device, mode of travel, environmental factors, and user attributes. New research in mobile spatial navigation systems has highlighted the importance of good design in terms of cognitive, perceptual, ergonomic and contextual factors and not simply a set of rules in a static interface [7]. Research into map-use context and mobile map adaptation also indicates that the context in which a navigation interface is used (time pressure, movement, lighting, and task complexity) should be in control of the interface [13], [14].

This is very applicable to consumer uses in China where BeiDou-based navigation can be applied to heterogeneous groups of users, such as students, office workers, delivery staff, elders and tourists, with unique needs and digital literacy levels. As a result, the assessment of UI requirements in this area should be done through a structured perspective that is not limited to single features but rather, group requirements into more general categories like functional, visual, interactional and adaptive requirements.

Despite the numerous helpful principles presented in the broader HCI and mobile usability literature, there is not much research directly connecting these concepts to BeiDou-based consumer navigation applications. Current

BDS research mostly talks about technical development, service architecture, augmentation, and precision improvement [1], [2], [3], [15]. They do not pay much attention to such issues as what interface features are thought to be most significant by users, how route guidance should be displayed in the BeiDou-enabled map, what type of alerts are most useful, or how to accommodate adaptive features to the needs of a real-world Chinese user. This introduces a distinct disjuncture between the technical prowess of the BeiDou ecosystem and design expertise required to create user-centric applications. Furthermore, due to the fact that modern navigation systems are more and more converging with A-GNSS, cloud assistance, and smart mobile services, the role of interface design is even more significant [3], [16].

In order to fill this gap, the current research is concerned with the analysis of user interface requirements of BeiDou-based consumer map navigation programs. Instead of providing a completed empirical study, this paper constructs a framework to do such work by determining the key categories of the UI requirement, summarizing the appropriate literature, and suggesting a conceptual framework to be used in evaluating and prioritizing it at a later stage.

UI requirements are addressed in this paper as a key design issue that ought to be systematically structured and subsequently evaluated by means of user surveys, empirical testing and multi-criteria prioritization tools. The paper puts special emphasis on the necessity to divide UI requirements into the following areas: map clarity, menu layout, visual symbols, route feedback, alert mechanisms, personalization and adaptive features [9]-[14], [17], [18]. This type of categorization can be helpful since it gives a viable transition between theory and design application. To this end, this paper hypothesizes a framework-based approach to the study of the UI of BeiDou-based consumer navigation systems in China.

The research is supposed to be used in future empirical research and requirement prioritization using tools like AHP, ANP and Fuzzy ANP but its primary focus in this context is to articulate, structure, and inspire the concerned UI requirements. In this way, the paper has a contribution to the convergence of satellite navigation, mobile cartography, and human-computer interaction. To be more precise, it provides three key contributions: it centralizes existing information on the design of mobile navigation interface and the context of BDS-based applications; it organizes the key categories of user interface requirements applicable to BeiDou-based consumer-oriented navigation applications; and it suggests a framework that can be used in the future to support the process of empirical validation and the prioritization of requirements. In this regard, the study is a valuable conceptual advancement to more practical, efficient, and user-friendly BeiDou navigation applications in the Chinese setting [7], [13], [17]–[20].

2. Literature Review

A. Mobile Map Usability and User Interface Design

The usefulness of mobile map navigation systems has been universally established as a key element influencing performance of tasks, user satisfaction and subsequent adoption. Compared to the traditional desktop-based systems, the mobile navigation applications have limitations of limited screen size, motion-based operation, divided attention, and time-based decision making. These attributes demand easy to use, understand, and cognitively efficient interfaces. The initial studies of mobile map usability pointed out that the design of interaction in navigation systems cannot be based on generic principles of interface design, but must consider technical, environmental and social issues [21]. On the same note, the wider scopes of mobile application usability evaluation have revealed that effectiveness, efficiency, learnability and satisfaction are leading dimensions of considering mobile systems, yet they are to be understood regarding mobility-related circumstances [22].

Studies of map-based interfaces have established that the layout of graphical controls and map features can affect user experience. Cybulski and Horbiowski proved that the position of the

buttons and the way maps are designed influence the performance in interaction and the perceived usability by users [23]. Their results are especially applicable to the field of navigation since consumers regularly touch zoom buttons, route buttons, search boxes, and orientation functions when they are in motion. Similarly, the recent developments in mobile cartography have emphasized the need of mobile-first thinking in maps and visualizations in mobile devices, where interaction operations, layout hierarchy, and readability should be tailored to touch-based interaction and limited displays [24]. These results indicate that user interface requirement in navigation systems cannot be considered as secondary implementation considerations; rather it is central design consideration that determine the overall usefulness of the application.

One more significant stream of literature is related to mobile interaction patterns which was the focus of a systematic mapping study by da Silva et al. who have defined a huge pool of mobile interaction design patterns which are grouped into several categories that solve common interface-related issues and solutions [25]. This is significant to the design of navigation applications since interfaces frequently apply shared mobile designs which may comprise bottom navigation, overlaying menus, floating controls and gesture-driven interfaces. Nevertheless, the map navigation applications also present further requirements that are not entirely reflected in the generic patterns, including the constant spatial orientation, quick visual processing, and real-time route directions. Thus, general mobile UI pattern studies are important to have a baseline; however, navigation systems demand more domain-specific requirement modeling.

User context has also been considered as an area of research interest in the use of mobile maps. Bartling et al. were of the opinion that mobile map application design must be closely related to the situation within which the map is applicable, such as user activity, situational demands and environmental considerations [26]. In reality, this implies that the interface requirements of a consumer navigation application can vary depending on whether the user is walking, driving, commuting on the public transport, or navigating through the unfamiliar urban environment.

Needs that are context sensitive can be larger visual cues, more conspicuous notifications, simplified route displays, or custom information density. There is a strong support of this literature to adaptive and context-sensitive UI requirements being part of any structured framework of BeiDou-based consumer navigation application.

B. Spatial Navigation, Cognitive Factors, and Interface Requirements

The Navigation systems are not technical tools only, rather cognitive aids. This is why several studies have investigated the issue of navigation in the context of spatial cognition and human decision making. Ruginski et al. conducted a review of interdisciplinary studies of mobile spatial navigation systems and suggested design principles based on cognitive science, geography, perception, and HCI [27]. In their work, it becomes evident that the success of users in their navigation tasks is not only determined by the information regarding the available routes but also the representation and delivery of this information by the interface. An ineffective map or warning system may lead to mistakes in route choice, decrease trust and cognitive overload. These results apply directly to consumer map navigation applications, where users tend to make quick decisions to dynamic scenarios.

Comparison of various modalities of navigation also illustrates the significance of interface design. Comparative studies of digital map interfaces and location-based augmented reality have discovered that various modalities can be used to support different facets of user experience, and that there are trade-offs between pragmatic efficiency and hedonic engagement [28]. This implies that the evaluation of UI requirements should not be limited to a single criterion, like speed or visual appeal, but should take into consideration various dimensions, such as clarity, efficiency, comprehensibility, and user preference. This further justifies the necessity of having organized

groups of UI requirements that involve not just functional controls but also visual and interaction-driven designs, when it comes to BeiDou-based applications.

The cognitive aspect of using mobile maps also indicates the significance of categorization of requirements. The consumers might require interfaces, which aid in quick route understanding, effortless symbol identification, minimal memory loading, and feedback uniformity. To this end, the literature indicates that the navigation systems UI requirements can be substantively classified into a set of requirements: functional requirements (e.g., search, routing, alerts), visual requirements (e.g., map legibility, color contrast, icons, legibility), interaction requirements (e.g., zooming, panning, menu organization), and adaptive requirements (e.g., context-based alerts, personal settings, simplification dynam This kind of classification comes in particularly handy when creating a framework paper since it will establish a clear outline of future empirical validation and prioritization.

C. GNSS, BeiDou, and the Need for User-Centered Consumer Navigation Design

Unlike the abundance of literature on mobile usability and map interaction, the literature on BeiDou Navigation Satellite System has mostly focused on technical advancement, performance enhancement, augmentation service, and positioning accuracy. Studies on BDS have reported how it has evolved into a global navigation system and its increased significance in transportation, communication and location-based services [29]. The recent development of high-precision BDS services also demonstrates the ongoing progress in timing, coverage, and accurate positioning support [30]. These papers affirm that BeiDou does offer considerable technical platform upon which consumers can navigate within China and even outside of the country, but they do not often discuss the layer of the user-facing interface that provides the experience of those possibilities.

This lack of balance between the technical development and interface-based assessment is a major problem. The evaluation of satellite architecture is not performed directly by consumer users, but the ease of use, understandability, visual clarity, and responsiveness of the navigation application are evaluated by consumers. Even a high-performance positioning system can create a bad user experience in case the interface is overloaded, disorganized, or not adjusted to the conditions of mobile usage. In this way, although BeiDou-related studies offer the technological explanation of the new consumer applications, the HCI and usability literature offers the design explanation of the new consumer applications being useful in practice. The issue is that these two literatures are not always interconnected.

In addition, this problem is even more significant in the Chinese context. It is projected that BeiDou-based consumer map navigation applications will benefit a wide and diverse range of users such as students, teachers, office employees, elderly people, and general consumers. Such users vary in terms of digital literacy, their capacity to read maps, mobility patterns, and language or cultural expectations. An interface that fits all the groups is then not likely to be appealing to all. This reinforces the view that BeiDou based navigation interfaces in China ought to be analyzed in the context of a special requirement framework that forms and assesses the most significant UI features in the eyes of the user.

D. Research Gap and Direction of the Present Study

Despite the valuable information given by the previous literature on mobile usability, map interface design and the technical development of BeiDou, the current literature lacks a clear framework of systematically assessing the user interface requirements of BeiDou-based consumer map navigation applications. Current literature is either on general mobile UI design, web-map interaction, or GNSS performance, but integrating these strands into user-centered model of BDS-enabled consumer applications [23]-[30] is not explicitly covered. Specifically, the literature lacks a clear indication of which

requirements of UI must be prioritized to have BeiDou-based consumer navigation systems in China, or it lacks a systematic categorization that could be used in future empirical research and multi-criteria prioritization.

Accordingly, this paper fills this gap by narrowing down the scope to identification of UI requirements, their classification and development of their frameworks. Instead of stressing on fulfilled empirical findings, the current research will focus on establishing a theoretical and methodological foundation of future research. The above literature analysis points to the fact that functional, visual, interaction, and adaptive requirements are the most applicable dimensions and that ultimately, these dimensions also need to be studied using user-centered empirical techniques and prioritization instruments. This renders the present study as a critical conceptual advancement to the future empirical analysis and prioritization of requirements based on methods like AHP, ANP and Fuzzy ANP.

3. User Interface Requirement Categories for BeiDou-Based Consumer Map Navigation Applications

The success of consumer map navigation applications depends on user interface requirements since they are the key to the effective access, interpretation and action of the navigation information by the user. The interface of BeiDou-based consumer map navigation apps cannot afford to just show maps and routes. It has to convert positioning information, route specifications, and user needs into a format that can be comprehended, effective, and applicable in the real-world mobile environment. There is consistent pre-existing evidence that interface organization, visual organization, interaction flow, and contextual adaptation are significant contributors to both navigation performance and user experience [21] through previous research on mobile map usability, spatial navigation system design, and graphical user interfaces. As such, the consideration of user interface requirements is an obligatory step towards enhancing usability and efficiency of BeiDou-enabled consumer navigation services in China.

In the current research, user interface requirements are classified into four key groups: functional requirements, visual requirements, interaction requirements, and adaptive requirements.

This taxonomy is suitable since it reflects both the operation-based and human-centered aspects of the design of the navigation applications. Functional requirements define what interface-supported functions the application is supposed to allow. The visual requirements are concerned with the display and readability of the spatial data. Interaction requirements deal with how users interact and manipulate the application as they navigate through it. Adaptive requirements are concerned with the capability of the interface to react to user circumstances, travel conditions and individual preferences.

The same categorization reasoning can be described in the previous studies on usability and mobile interaction that provide that structuring of requirements enhances clarity of design and subsequent evaluation of the design [22], [24], [25].China has different user groups, which might have different navigation patterns, expectations, and interface preferences. Students, office workers, drivers, elderly users, tourists and general users are important consumer segments as demonstrated in Fig. 1 and whose needs must be taken into account when designing BeiDou-based navigation interfaces.

USER GROUP	TYPICAL CHARACTERISTICS	KEY NAVIGATION NEEDS	CRITICAL UI EXPECTATIONS
Students	• Tech-savvy, frequent mobile users • Often use navigation for campus, public transport, and social activities • Cost sensitive, prefer free or low-data options	Campus navigation Public transport guidance POI (cafes, libraries, services) search Time-efficient shortest routes	Simple interface with fast search Clear routes and easy-to-follow steps Low data usage and quick loading Minimal distractions and clean layout
Office Workers	• Time-sensitive, daily commuters • Multitaskers with tight schedules • Rely on real-time traffic updates • Use navigation for work-related trips	Fastest and most reliable routes Real-time traffic & incident alerts ETA prediction and route updates Nearby services (fuel, parking, food)	Quick access to key functions Real-time info with minimal steps Turn-by-turn clarity and lane guidance Consistent and intuitive navigation flow
Drivers	• Focus on road safety and efficiency • Concerned with speed and accuracy • Often travel in unfamiliar areas • High dependence on voice guidance	Turn-by-turn driving guidance Traffic alerts, accidents, road hazards Speed limit and speed camera alerts Gas stations, rest areas, parking	Clear voice guidance Large maps and easy-to-read text Low-glare, night-mode friendly design Distraction-free and safe interaction
Elderly Users	• Lower digital literacy • Prefer simplicity and clarity • Need more time to read and interact • Reliance on basic navigation features	Basic navigation & step-by-step guidance Voice guidance with clear instructions Nearby services (hospitals, pharmacies) Safe and easy walking/driving routes	Large text and high-contrast interface Simple layout with fewer options Voice support and easy confirmation Large buttons and easy touch targets
Tourists / Travelers	• Unfamiliar with local environment • Explore new places and attractions • May face language and connectivity issues • Rely on maps for exploration and discovery	POI discovery (attractions, hotels, food) Offline maps and navigation Multi-language support Route suggestions and sightseeing	Offline access to maps and data Multi-language UI and voice support Clear landmarks and visual cues Easy planning and itinerary features
All Users (General)	• Wide range of age, skills, and needs • Use app in diverse environments • Expect reliability and consistency • Value privacy and data security	Accurate navigation and positioning Route alternatives and re-routing Alerts and important notifications Privacy and data protection	Reliable, consistent, and trustworthy UI Personalized preferences and settings Works well across devices and networks Secure and privacy-respecting experience

Fig. 1. Major user groups, typical characteristics, key navigation needs, and critical UI expectations in BeiDou-based consumer map navigation applications.

Figure 1 shows the consumer users groups related to map navigation applications based on BeiDou technology and discusses their characteristics, requirements for navigation, and important interface aspects. It can be seen from the chart that requirements cannot be homogeneous for all types of users. On the contrary, successful interface design needs to consider differences in digital skills of users, purpose of trips, situations, and user interface requirements.

3.1 Functional User Interface Requirements

Functional UI Requirements relate to the capabilities offered by the interface which enable users to execute navigation tasks. These include destination searching, route planning, re-routing, turn-by-turn navigation, presentation of traffic incidents, and proximity to points of interest. While these are regarded as system functions, they also constitute an important part of the UI as their effectiveness relies on how well they are provided for in the interface itself. The process of rerouting could be performed perfectly, yet failure to convey the information in an appropriate manner may render the function useless for the user.

Studies carried out in relation to web-map graphical UIs indicate that the structure and controls used impact greatly on task completion efficiency [23], [26]. Therefore, the term 'functional requirements' is defined as interface-related features designed to facilitate execution of tasks by providing necessary functionality in an efficient manner.

As for the Chinese consumer maps using the Beidou technology, the following could be considered as functional requirements: localized routing data, effortless switching between modes of transport, route summaries, and presentation of location based services. consumer users often depend on navigation applications in time-sensitive and changing travel situations, these functions should be interface-accessible with minimal effort. Thus, functional UI requirements form a foundational category in the proposed requirement

structur.

3.2. Visual User Interface Requirements

The visual requirements are associated with the presentation, readability, and clear visibility of interface components responsible for displaying navigation data. Map clarity, route marking, icon readability, contrast, text readability, and visual hierarchy are among the aspects that should be considered when designing such an interface. Visual requirements are particularly relevant for mobile navigation applications since users will be dealing with the interface on a comparatively small screen size and under varying environmental conditions, including movement, insufficient light, or distractions.

According to previous research, the graphical structure of map interfaces affects both attention and efficiency of interaction with those interfaces [23]. Responsive designs for web maps on smartphones have also been found to influence their efficiency [26]. In the case of navigation systems relying on the BeiDou constellation, visual requirements become extremely crucial since positioning needs to be transformed from numbers into a visual image.

It means that the route being followed, alternative routes, directionality, traffic signs, and destination symbols need to be presented to users visually. Visual overload and poor organization can confuse even users who receive accurate navigation information. As shown by recent research on mobile maps and usability, effective visual representation decreases the cognitive load and enables fast spatial understanding [21], [23], [27].

3.3. Interaction User Interface Requirements

The interaction requirement is related to how users control and operate the interface when navigating through it. This includes interactions such as zooming and panning, search interactions, accessing menus, gestures, screen transitions, and task actions. Studies have shown that repetitive patterns affect the outcome of interaction design and that frequent tasks should be executed through predictable interactions [24]. In map-based applications, it is especially critical to consider control placements and interaction requirements since interaction usually happens in motion and time pressures [23], [26].

When it comes to consumer navigation applications, it is important to take into account the interaction requirement for the following reason. Consumers might have to check their route information while doing other activities such as walking or driving. Hence, consumers would like to easily interact with the interface and reach an important function in a quick way. Menu design should make sense to consumers and control should be placed logically on the interface. It is also necessary to make gesture interactions understandable to consumers. All these are significant in consumer navigation within China since the difference between user groups is expected to exist significantly.

3.4. Adaptive User Interface Requirements

Adaptive requirements are all about how the interface can change based on what users need, the conditions of their travel, the environment, or even the state of the application itself. In navigation systems, having interfaces that are aware of context and can adapt really helps users out. They can tweak how much info is shown, when alerts go off, simplify displays, or even personalize content related to routes.

Research on mobile navigation systems shows just how crucial it is to design with context and human needs in mind. More recent studies on mobile maps and neuroadaptive systems indicate that future navigation interfaces should be more flexible, allowing for dynamic interactions that respond to people, tasks, and the environment. For navigation apps using BeiDou, this means they could offer personalized route options, real-time alerts, adjustments based on how you're traveling, and easier-to-use interfaces

3.5. Summary of Requirement categories

Based on what we discussed the main user interface needs for BeiDou-based map navigation apps can be grouped into four areas: functional visual interaction and adaptive. This four-part

structure helps organize interface needs in a way before testing and prioritizing them. It also matches what other experts have found in studies on usability map interaction and designing for different situations [21]–[29].

These four categories are the foundation for the framework I'll present next. They can also help prioritize needs using tools, like AHP, ANP and Fuzzy ANP. The four categories. Functional, visual interaction and adaptive. Will help us create a better BeiDou-based map navigation app. We will use these categories to support prioritization. To provide a consolidated view of the proposed requirement structure, Fig. 2 presents the detailed categorization of user interface requirements, their representative codes, descriptions, and intended usability benefits.

CATEGORY	REQUIREMENT CODE	DETAILED REQUIREMENT DESCRIPTION	PURPOSE / BENEFIT
Functional Requirements	F1	Efficient destination search with auto-suggestions and history	Helps users quickly find and set destinations
	F2	Multiple route options with estimated time and distance	Allows users to choose the most suitable route
	F3	Real-time traffic information and congestion alerts	Helps avoid delays and supports informed decisions
	F4	Turn-by-turn voice and visual navigation guidance	Ensures users follow the route accurately
	F5	Route recalculation based on traffic or position changes	Keeps navigation accurate in dynamic conditions
	F6	Nearby places (POI) search and categorization	Supports users in finding essential services nearby
	F7	Offline map access and download management	Ensures usability in low-connectivity areas
Visual Requirements	V1	Clear map layout with appropriate zoom levels	Improves readability and spatial understanding
	V2	High contrast and readable text for all screen conditions	Ensures visibility in bright and low-light environments
	V3	Distinct route highlighting and direction indicators	Helps users easily follow the suggested route
	V4	Consistent and meaningful icon design	Enhances recognition and reduces confusion
	V5	Minimal clutter and well-structured information hierarchy	Reduces cognitive load and improves focus
	V6	Support for day/night mode and color-blind friendly design	Ensures comfort and accessibility for all users
Interaction Requirements	I1	Easy zoom, pan, and rotate controls	Allows users to explore the map smoothly
	I2	Intuitive menu structure and quick access to key functions	Reduces steps and improves task efficiency
	I3	Gesture support (pinch, swipe, long press, etc.)	Enhances natural and fast interaction
	I4	Voice input for search and navigation commands	Supports safer hands-free operation
	I5	Quick access to route summary and trip details	Helps users review information at a glance
	I6	Smooth transitions and minimal loading delays	Improves overall interaction satisfaction
Adaptive Requirements	A1	Personalized route recommendations based on user habits	Provides relevant and user-preferred routes
	A2	Adaptive information density based on speed and context	Shows more details when needed, less when moving
	A3	Context-aware alerts (speed limits, hazards, weather, etc.)	Enhances safety and situational awareness
	A4	Automatic adjustment for travel mode (driving, walking, transit)	Optimizes interface for specific navigation needs
	A5	User preference settings and profile management	Offers a customized and consistent experience
	A6	Adaptive voice guidance volume based on environment	Improves clarity without causing distraction

Fig. 2. Detailed categorization of user interface requirements for BeiDou-based consumer map navigation applications, including requirement codes, descriptions, and expected benefits.

Fig. 2 visually summarizes the major user interface requirement categories identified in this study, namely functional, visual, interaction, and adaptive requirements. In addition to listing representative requirement codes, the figure also highlights the practical purpose and usability benefit of each requirement. This structured representation supports clearer requirement .

Table 1. User Interface Requirement Categories for BeiDou-Based Consumer Map Navigation Applications

Requirement Category	Description	Example Elements
Functional Requirements	Interface-supported capabilities for performing core navigation tasks	destination search, route generation, route recalculation, alerts, nearby places

Visual Requirements	Presentation and readability of navigation information	map clarity, route highlighting, icon visibility, text readability, color contrast
Interaction Requirements	User control and manipulation of the interface	zoom/pan controls, menu organization, gesture support, search flow, screen transitions
Adaptive Requirements	Context-aware and personalized interface behavior	personalized alerts, route preferences, adaptive display density, travel-mode-based adjustments

4. Proposed Framework for Evaluating User Interface Requirements

The Designing user-centered interfaces for BeiDou-based consumer map navigation applications requires a systematic approach that integrates requirement identification, evaluation, and prioritization. Based on the four requirement categories identified in Section III — functional, visual, interaction, and adaptive — this section presents a conceptual framework that provides a structured method for evaluating and prioritizing UI requirements, laying the foundation for future empirical studies. The framework is applicable to mobile navigation applications in China and other BeiDou-enabled contexts.To illustrate the overall structure of the proposed approach, Fig. 3 presents the integrated framework for evaluating and prioritizing user interface requirements in BeiDou-based consumer map navigation applications.

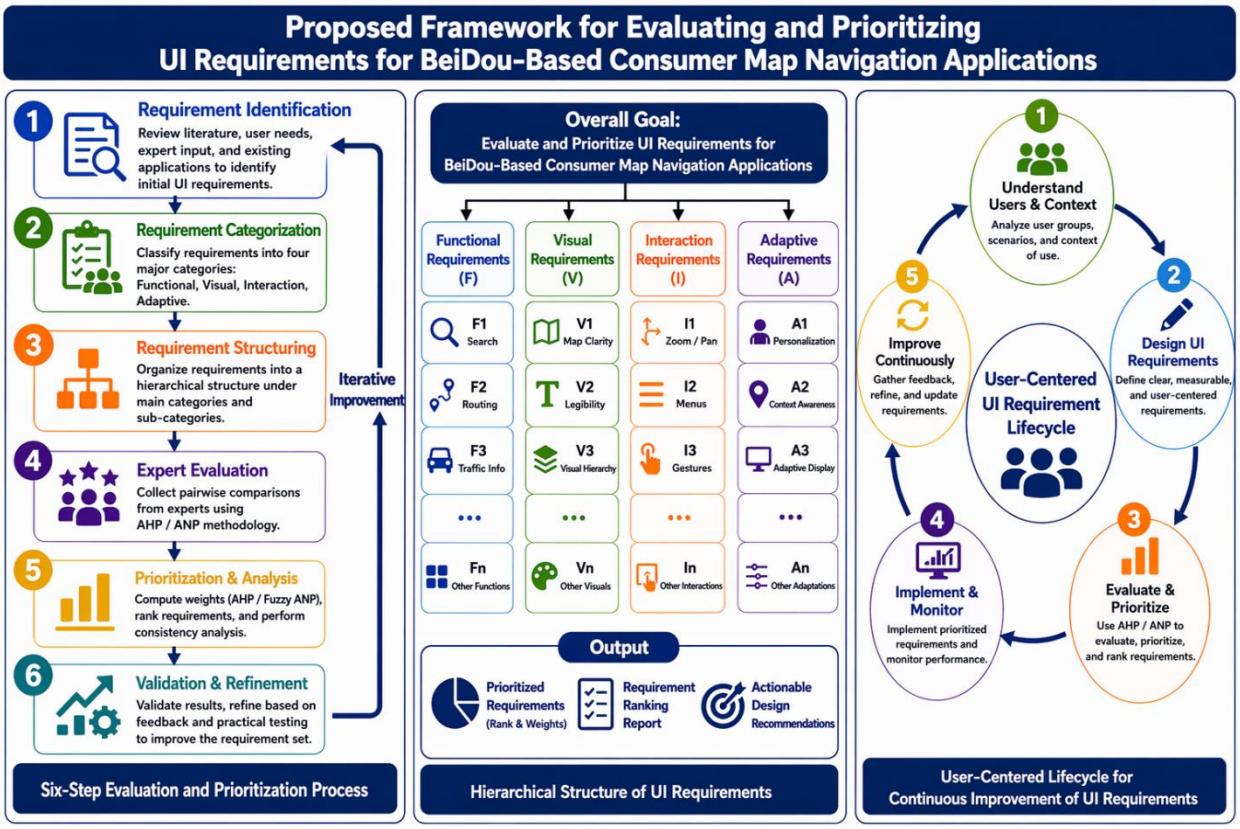

Fig. 3. Proposed framework for evaluating and prioritizing user interface requirements for BeiDou-based consumer map navigation application

Fig. 3 provides an integrated view of the proposed framework. It combines the six-step evaluation and prioritization process, the hierarchical organization of user interface requirement categories, and the user-centered lifecycle for continuous refinement. The figure shows that UI requirement evaluation should begin with requirement identification and categorization, proceed through structured assessment and prioritization, and continue through iterative validation and improvement. This framework offers a practical foundation for future empirical study and multi-criteria prioritization using methods such as AHP, ANP, and Fuzzy ANP.

4.1 Framework Overview

The proposed framework consists of five major stages:

Input: Interface Prototypes or Screenshots

- The evaluation process begins with either real application screenshots or prototype mockups of the navigation interface.
- This ensures that participants or evaluators interact with realistic representations of functional, visual, interaction, and adaptive UI elements [21], [22].

Requirement Assessment: Survey and Expert Feedback

- Participants (e.g., students, teachers, general consumers) evaluate UI elements via structured surveys.
- Surveys include Likert-scale ratings, ranking tasks, and open-ended questions to capture both quantitative and qualitative feedback [23], [24].
- Expert panels can also provide input to validate the relevance and completeness of requirements.\

Data Analysis: Statistical and multi-criteria Evaluation

- Collected data are analyzed using descriptive statistics to identify trends and average user ratings for each requirement.
- Priority ranking and multi-criteria decision-making techniques, such as AHP, ANP, and Fuzzy ANP, are applied to determine the relative importance of each UI element, considering interdependencies among requirements [25], [26].

Output: Ranked UI Requirements and Design Guidelines

- The analysis produces a prioritized list of UI requirements, highlighting the most critical elements for design focus.
- Design guidelines are generated to assist developers in optimizing interface layout, visual clarity, interaction efficiency, and context-aware adaptation.

Future Work Loop: Empirical Validation and Iterative Refinement

- The framework is designed to support future empirical studies, where actual user testing can validate the proposed prioritization.
- Results from empirical studies feed back into the framework, allowing iterative refinement and continuous improvement of UI design

4.2 Framework Diagram

The conceptual workflow can be visualized as follows (to be inserted as a figure in the paper):

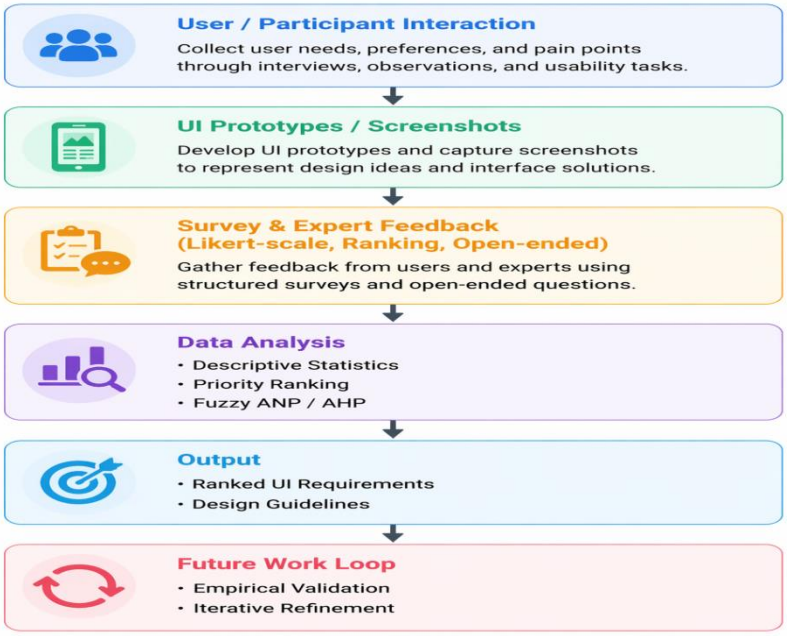

Fig. 4. Proposed Framework for Evaluating BeiDou UI Requirements

Table 2. Proposed Framework for Evaluating

Stage	Activities	Expected Output
Input	Collect application prototypes or screenshots	Interface elements to be evaluated
Requirement Assessment	Conduct surveys and expert reviews	User ratings and qualitative feedback for each UI requirement
Data Analysis	Apply descriptive statistics, ranking, AHP/Fuzzy ANP	Relative importance of UI requirements
Output	Generate prioritized list and design guidelines	Ranked UI elements; actionable design recommendations
Future Work Loop	Plan empirical validation and iterative refinement	Updated framework and validated requirements

4.3 Key Advantages of the Proposed Framework

- Structured Evaluation – Organizes UI requirements into categories, providing clarity for analysis.
- User-Centered Focus – Integrates both consumer feedback and expert validation.
- Prioritization-Ready – Enables application of multi-criteria decision-making methods for ranking critical UI elements.
- Future-Proof Design – Supports iterative empirical studies and continuous refinement of interface design.
- Adaptability – Applicable to various user groups, device types, and BeiDou-enabled navigation applications in China.

of lag in collaborative momentum [15], [16], [21], [27], [28], [29].

In addition to requirement categorization and evaluation, it is also important to understand how user interface requirements are connected with the broader architecture of a BeiDou-based consumer map navigation application. In such applications, the user interface is not an independent visual layer separated from the technical system. Instead, it works as the main bridge between BeiDou positioning services, data processing modules,

route generation functions, adaptive service delivery, and user feedback mechanisms.

For example, accurate positioning data from BeiDou can only become useful for ordinary users when it is presented through a clear map display, readable route lines, understandable icons, and timely navigation alerts. Similarly, route calculation and traffic information must be translated into simple interface elements that users can quickly understand during walking, driving, or commuting. This shows that the quality of the interface directly affects how effectively technical navigation services are experienced by users.

A technical view of UI requirement integration is therefore necessary because it explains how interface requirements interact with system components and service outputs. Functional requirements are linked with routing, searching, and alert modules. Visual requirements are linked with map rendering, icon design, route highlighting, and display clarity. Interaction requirements are connected with user control, menu access, touch gestures, and navigation flow. Adaptive requirements are related to context-aware services, user preferences, mobility conditions, and real-time feedback.

By examining these connections, researchers and developers can better understand how UI requirements support the complete navigation process. This integrated perspective also helps ensure that the proposed framework is not limited to surface-level design issues, but is connected with the actual operation of BeiDou-based consumer navigation systems. As a result, UI evaluation can become more practical, system-oriented, and useful for future design improvement.

outputs.

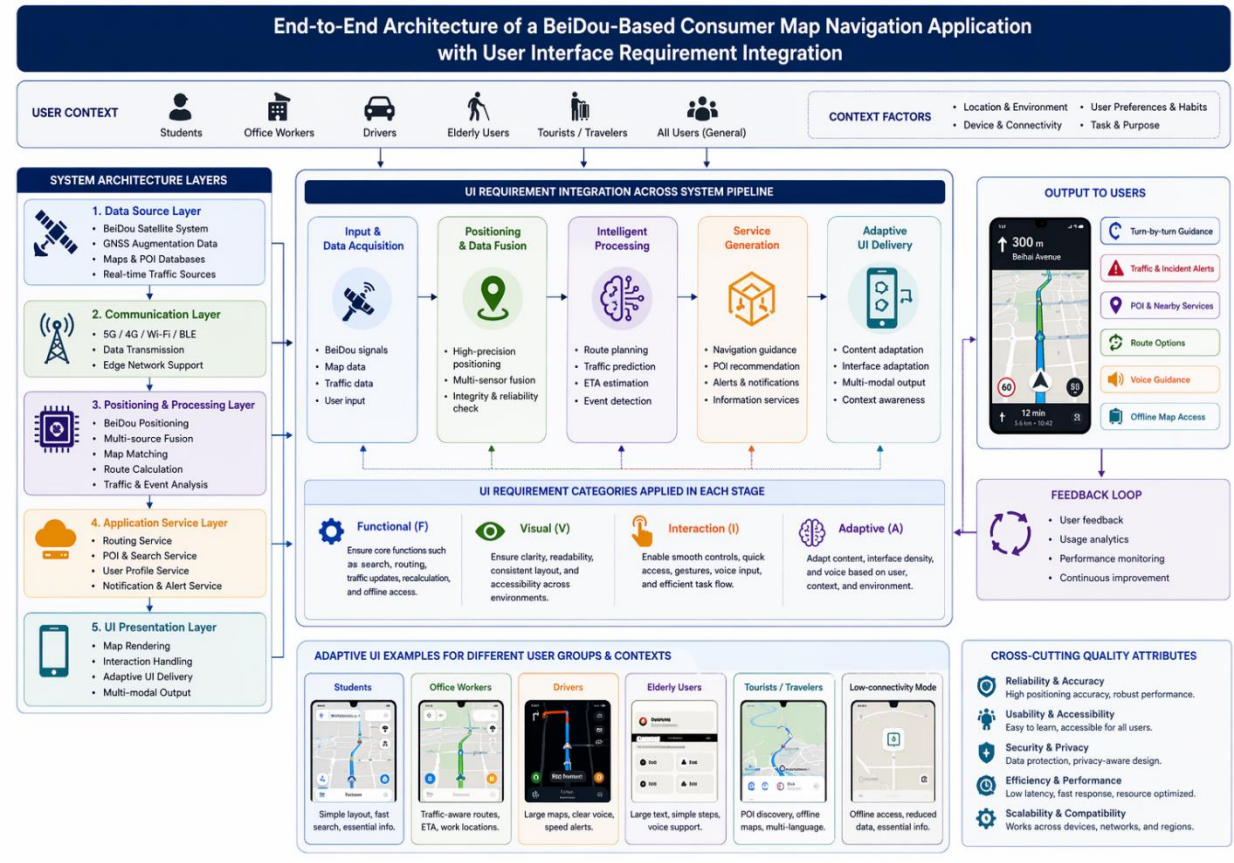

Fig. 5. Technical integration of user interface requirements within the architecture of a BeiDou-based consumer map navigation application.

4.4 Simulation-Based Evaluation of UI Requirements

To evaluate and prioritize user interface requirements more effectively, this study proposes the use of a simulation-based evaluation approach. This approach can help researchers and designers examine different interface designs under various navigation situations, user conditions, and environmental contexts. In the case of BeiDou-based consumer map navigation applications, simulation can combine user feedback, UI prototypes, BeiDou positioning data, mobility scenarios, and environmental factors to create a more controlled and realistic evaluation setting.

The purpose of using simulation is to observe how different UI elements may perform before full-scale implementation. For example, map clarity, route highlighting, alert notifications, menu layout, and adaptive display features can be tested under different conditions such as walking, driving, heavy traffic, low visibility, or unfamiliar locations. This allows researchers to identify possible usability problems early and understand which interface elements require improvement.

A simulation-based approach is also useful because navigation applications are used in dynamic real-world environments. Users may interact with the application while moving, making quick decisions, or responding to changing route conditions. Therefore, evaluating the interface only in a static setting may not fully reflect actual user experience. By simulating different usage scenarios, the evaluation process becomes more practical and closer to real navigation behavior.

In the context of BeiDou-based consumer map navigation applications, simulation can also help examine how positioning information is converted into user-facing interface outputs. For example, BeiDou location data may support accurate route tracking, but the usefulness of this information depends on how clearly it is displayed on the map. If the route line, current location marker, warning message, or direction indicator is not visible or understandable, the technical accuracy of the system may not lead to a positive user experience. Therefore, simulation can help evaluate the connection between technical navigation functions and interface usability.

This approach can also support comparison between different design alternatives. For example, researchers may compare two different map layouts, alert styles, menu structures, or adaptive display settings to determine which version provides better clarity and user comfort. Such comparison can help reduce design errors before real-world deployment. It can also support decision-making by showing which UI elements are more effective under specific travel conditions.

Another advantage of simulation-based evaluation is that it can include different user groups and mobility contexts. Students, office workers, drivers, elderly users, tourists, and general consumers may have different expectations from navigation interfaces. Some users may prefer simplified maps, while others may need detailed route information or personalized alerts. By simulating different user profiles and travel scenarios, the evaluation can become more inclusive and user-centered.

In this study, the simulation-based evaluation approach supports the overall framework by linking interface requirements with user experience outcomes. It can help compare alternative UI designs, measure expected usability performance, and provide input for further prioritization using methods such as AHP, ANP, and Fuzzy ANP. As a result, the approach can support the development of more usable, adaptive, and user-centered BeiDou-based navigation interfaces.

Overall, simulation provides a practical bridge between conceptual requirement analysis and future empirical validation. It allows researchers to test ideas, observe possible interface weaknesses, and refine design priorities before conducting large-scale user studies. This makes the proposed framework more systematic and suitable for future development of BeiDou-enabled consumer navigation applications in China.

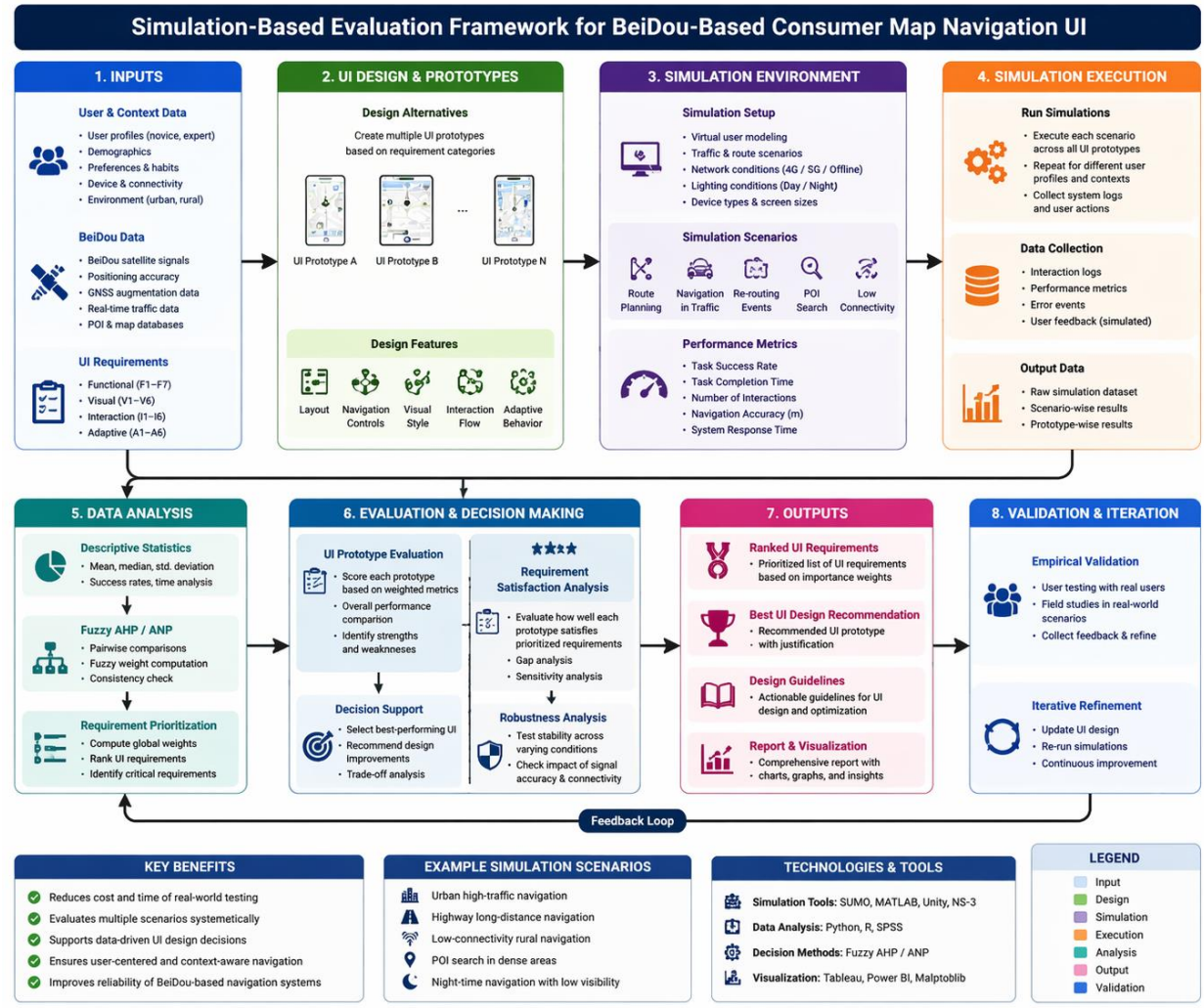

Fig. 6. Simulation-based evaluation framework for BeiDou-based consumer map navigation UI, showing the full flow from inputs, UI design, simulation, analysis, outputs, and iterative feedback loop.

4.5 Graphical Representation of Proposed UI Requirement Evaluation

To make the proposed evaluation framework clearer, this section presents a set of graphical illustrations related to the analysis of user interface requirements in BeiDou-based consumer map navigation applications. These graphs help explain how different UI requirement categories, interface variables, evaluation stages, and prioritization methods can be understood in a more visual and organized way.

The values presented in these graphs are only illustrative. They are used to demonstrate how the proposed evaluation process may work in future studies. In the next stage of research, actual survey responses and expert judgments will be used to calculate the final requirement scores, priority rankings, and usability outcomes.

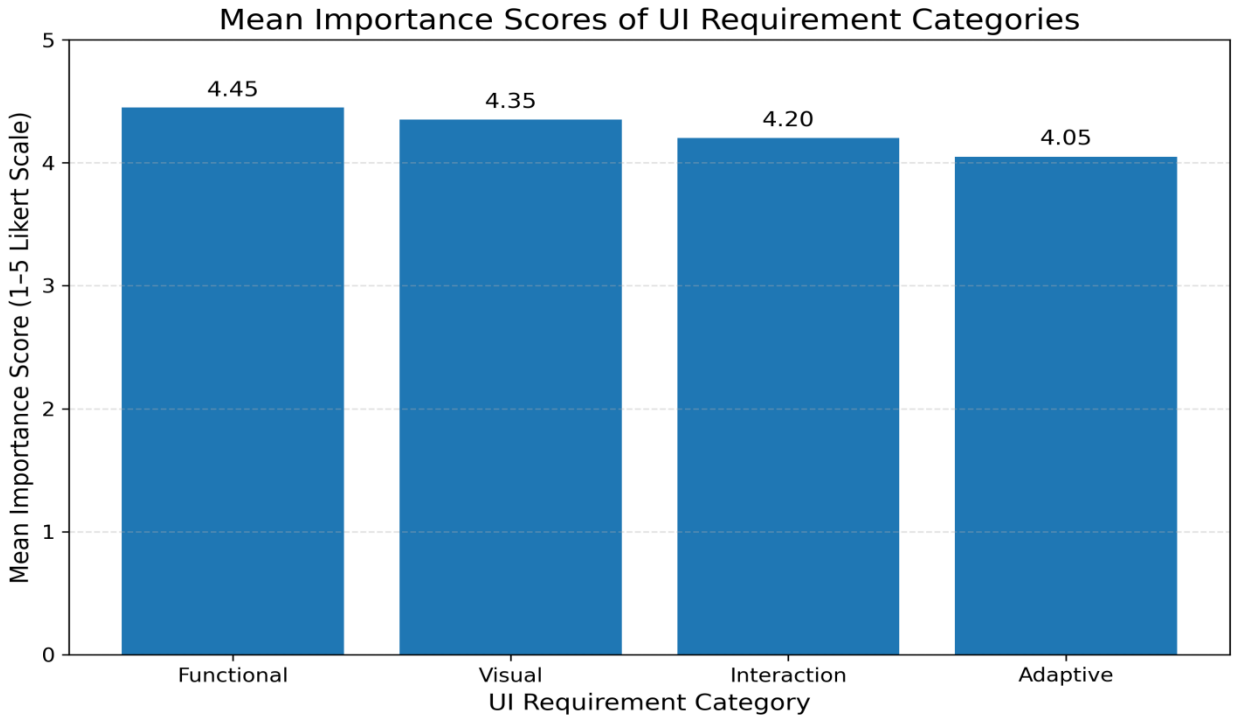

Fig. 7. Conceptual importance scores of user interface requirement categories for BeiDou-based consumer map navigation applications.

Fig. 7 presents the conceptual importance scores of the four main UI requirement categories: functional, visual, interaction, and adaptive requirements. Functional and visual requirements are shown with higher values because they directly support navigation task performance, route understanding, and map readability. Interaction and adaptive requirements are also important because they improve ease of use, personalization, and context-aware navigation support.

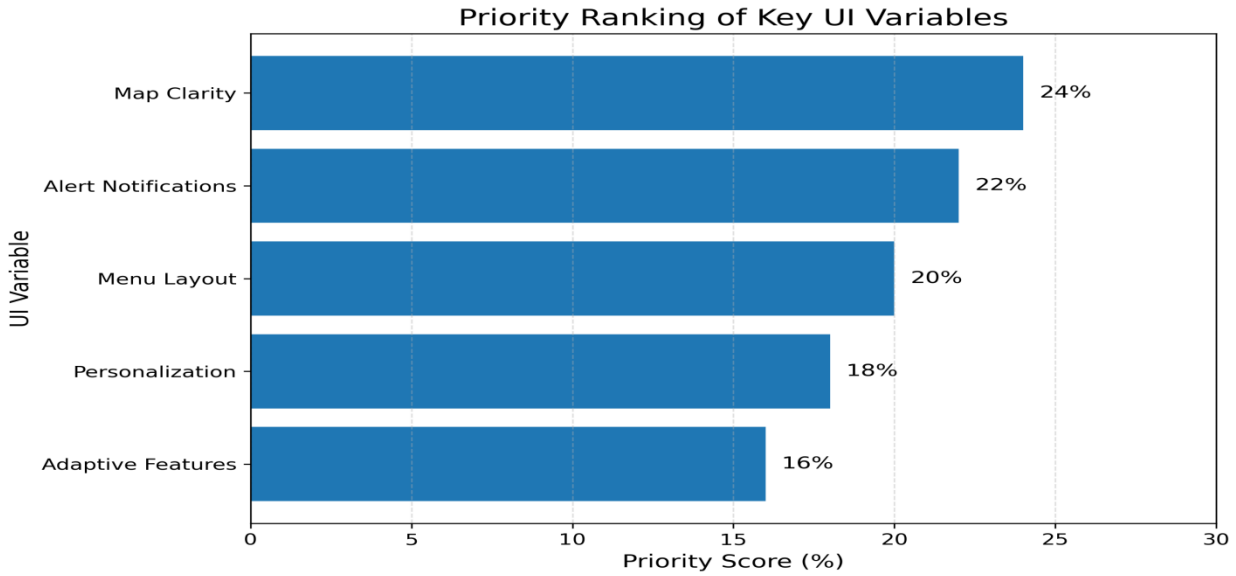

Fig. 8. Conceptual priority ranking of key UI variables in BeiDou-based consumer map navigation applications.

Fig. 8 shows the conceptual priority ranking of key UI variables, including map clarity, alert notifications, menu layout, personalization, and adaptive features. This graph demonstrates how survey responses or expert judgments can be converted into priority scores.

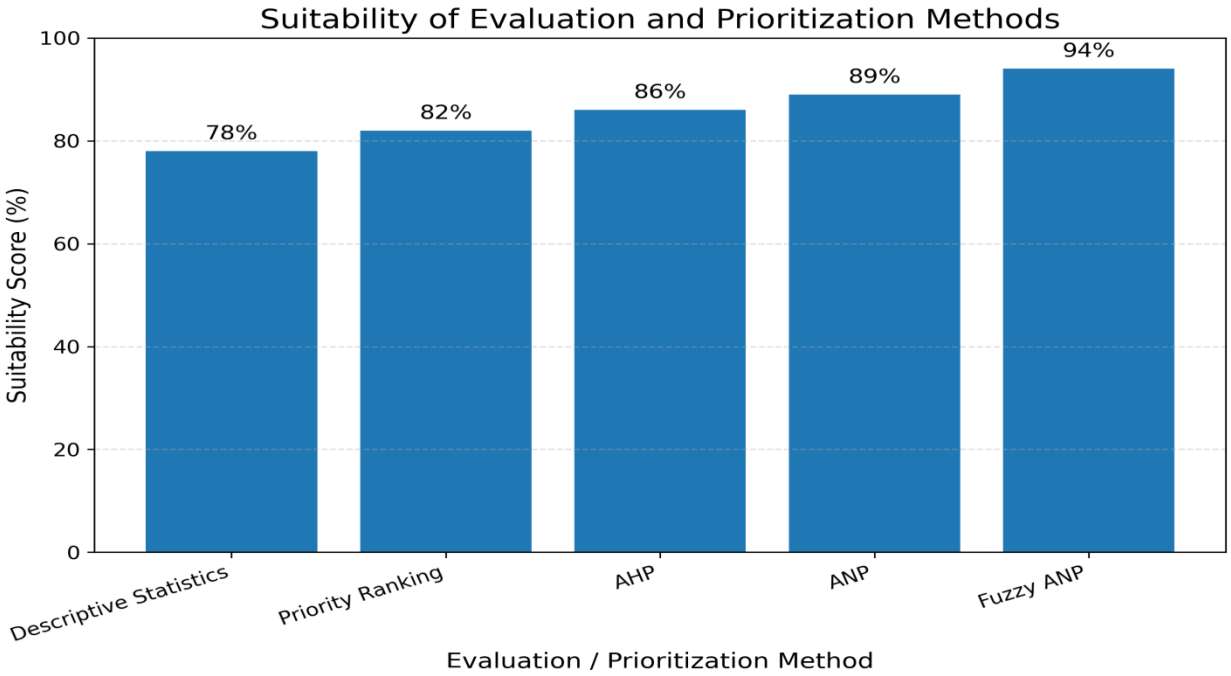

Fig. 9. Simulated usability improvement across different UI evaluation and refinement stages.

Fig. 9 illustrates the expected improvement in usability across different evaluation stages. The graph shows that usability may improve gradually from the initial prototype stage to user survey, expert review, Fuzzy ANP-based prioritization, and refined UI design. This supports the iterative nature of the proposed framework.

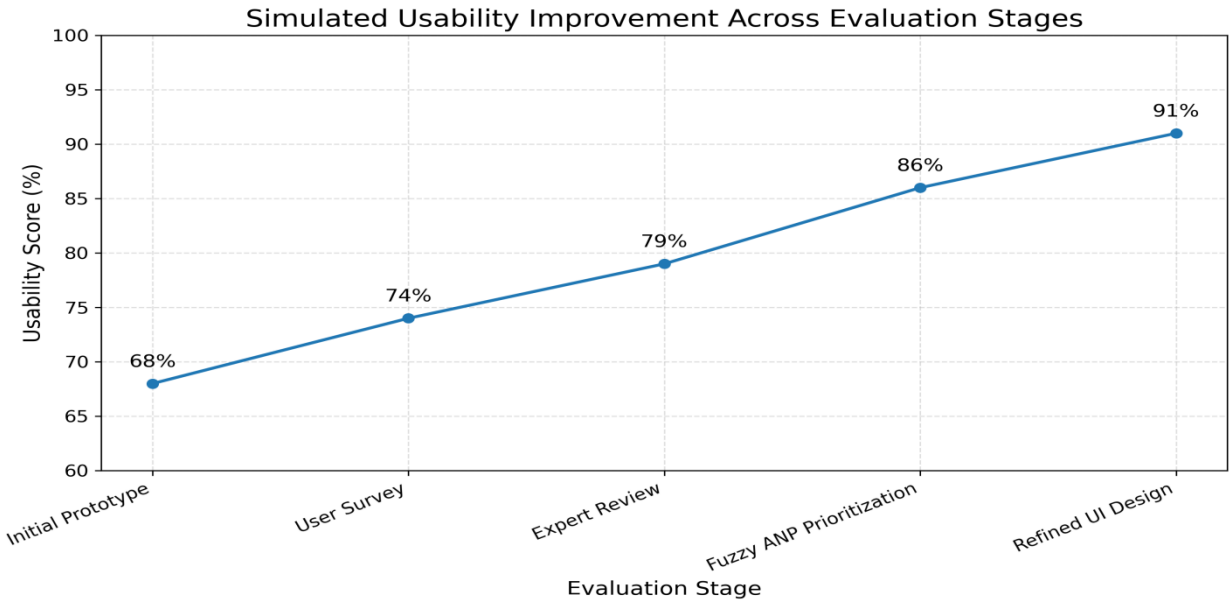

Fig. 10. Conceptual suitability of evaluation and prioritization methods for UI requirement analysis.

Fig. 10 compares the suitability of different evaluation and prioritization methods, including descriptive statistics, priority ranking, AHP, ANP, and Fuzzy ANP. Fuzzy ANP is shown as highly suitable because it can handle uncertainty in expert judgments and consider interdependencies among UI requirements

Table 2. Future Research Table

Focus Area	Method / Measurement	Purpose Expected Outcome
Empirical UI Validation	User testing, surveys, task performance metrics	Confirm usability and relevance of UI requirements
Context-Aware Evaluation	Field studies in different mobility scenarios	Assess interface performance under real-world conditions
Requirement Prioritization	AHP, ANP, Fuzzy ANP	Generate a weighted list of critical UI elements
Adaptive Features Testing	Prototype evaluation, user feedback	Evaluate dynamic interface behavior and personalization effectiveness
User Diversity Analysis	Demographic segmentation, subgroup comparison	Ensure interface accessibility and usability across populations
Multi-Device Consistency	Cross-platform testing	Validate UI consistency on smartphones, tablets, and other devices

5. Future Work

This study presents a conceptual framework for evaluating user interface requirements in BeiDou-based consumer map navigation applications. The main focus of the paper is to organize UI requirements into clear categories and propose a structured approach for their evaluation. However, further research is needed to test and validate the framework through empirical data. Future work will therefore focus on user-based evaluation, expert feedback, and requirement prioritization to confirm the practical usefulness of the proposed framework.

A. Empirical Validation

Future studies will conduct user-centered empirical evaluations of BeiDou-based navigation applications in China. These studies may include:

Controlled usability testing: Participants will perform typical navigation tasks using prototypes or real applications, allowing measurement of task completion time, error rates, and user satisfaction.

Context-aware evaluation: Testing interfaces in real-world settings, such as walking, driving, or commuting, to assess the impact of environmental and situational factors on usability.

User diversity analysis: Including participants of different ages, occupations, and digital literacy levels to ensure that the interface is broadly accessible.

These empirical studies will provide quantitative and qualitative data to refine the framework, validate requirement categories, and inform the relative importance of UI elements.

B. Prioritization of Requirements

Following empirical evaluation, requirement prioritization will be conducted using multi-criteria decision-making methods. Potential approaches include:

Analytic Hierarchy Process (AHP): Participants and experts provide pairwise comparisons of UI elements to derive relative importance weights.

Analytic Network Process (ANP): Extends AHP by considering dependencies and feedback among UI elements.

Fuzzy ANP: Introduces fuzzy logic to handle uncertainty and subjective judgment, particularly useful when evaluating adaptive or context-aware requirements.

The combination of empirical results and structured prioritization techniques will generate a ranked list of critical UI requirements, guiding designers and developers in focusing on the most impactful interface elements.

C. Exploration of Adaptive and Context-Aware Features

Future research should also explore adaptive interface mechanisms, including:

Dynamic alerts and notifications: Adjusting timing, frequency, and content based on user context and cognitive load.

D. **Personalized route preferences:** Adapting route suggestions according to user behavior, historical choices, or accessibility needs.

Display simplification in complex environments: Modifying map detail and visual density in situations requiring rapid comprehension, such as high-traffic areas.

By incorporating these features, future studies will ensure that BeiDou-based navigation interfaces are both flexible and user-centered, supporting diverse scenarios and user groups.

6. Conclusion

This paper presents a conceptual framework for evaluating user interface requirements in BeiDou-based consumer map navigation applications. The study argues that technical accuracy alone is not enough to ensure a good user experience. Although BeiDou can provide accurate positioning and navigation support, users mainly interact with the system through maps, menus, alerts, icons, route displays, and other interface elements. Therefore, user-centered interface design is essential for converting satellite-based navigation data into clear, useful, and practical guidance for users. Based on the review of literature related to mobile usability, map-based interfaces, and spatial navigation systems, this paper identifies a research gap in the evaluation of UI requirements for BeiDou-enabled consumer navigation applications in China.

The study classifies UI requirements into four main dimensions: functional, visual, interaction,

and adaptive requirements. Functional requirements refer to the main navigation tasks supported by the interface, such as destination search, route generation, route recalculation, and real-time alerts. Visual requirements focus on the clarity and readability of interface elements, including map clarity, icons, route highlighting, text visibility, and layout organization. Interaction requirements relate to the way users control and operate the application, such as menu navigation, touch gestures, zooming, panning, and screen transitions. Adaptive requirements focus on personalized and context-aware interface behavior, including route customization, dynamic alerts, travel-mode-based adjustment, and simplified map display in complex environments. This classification provides a clear basis for analyzing and prioritizing UI elements in future empirical studies.

To support the evaluation of these requirements, this paper proposes a framework that combines interface prototypes, user feedback, expert review, statistical analysis, and multi-criteria decision-making methods such as AHP, ANP, and Fuzzy ANP. The framework is designed to guide future empirical evaluation and iterative improvement of BeiDou-based navigation interfaces. Through this process, researchers and developers can identify the most important UI elements and develop practical design recommendations for different user groups, travel conditions, and mobility scenarios. The tables and figures included in this study further explain the requirement categories, evaluation stages, and possible future research directions.

The proposed framework makes several contributions. First, it connects the technical capabilities of the BeiDou Navigation Satellite System with user experience and interface design considerations. Second, it organizes UI requirements into a manageable structure that can support both academic analysis and practical design work. Third, it provides a direction for future empirical studies in which user surveys, expert feedback, and prioritization methods can be used to validate and refine the proposed requirements. Finally, the framework highlights the importance of adaptive and context-aware design, especially because navigation applications are used in changing travel situations and by diverse user groups.

In conclusion, this study provides a foundation for future evaluation and prioritization of UI requirements in BeiDou-based consumer map navigation applications. By combining requirement classification, framework development, and planned multi-criteria analysis, the study supports the design of more usable, efficient, and user-centered navigation interfaces. Future research involving empirical testing, adaptive interface evaluation, and Fuzzy ANP-based prioritization can further improve the practical value of the proposed framework and help meet the needs of different consumer users across China.

7. Declaration

7.1 Author Contributions

Atta ur Rahman: Conceptualized the study and developed the main research idea. Defined the research problem, objectives, scope, and overall structure of the paper. Conducted the literature review on BeiDou Navigation Satellite System, mobile map usability, user interface requirements, and requirement prioritization methods. Identified and organized the major user interface requirement categories, including functional, visual, interaction, and adaptive requirements. Developed the proposed conceptual framework, simulation-based evaluation approach, graphical representations, tables, and future research directions. Prepared the initial manuscript draft, revised the paper content, formatted the sections, and finalized the manuscript for submission.

Fahim Muhammad Khan: Provided academic guidance and intellectual support during the development of the study. Reviewed the research direction, helped refine the structure of the paper, and provided feedback on the conceptual framework and requirement categorization. Contributed to improving the clarity, coherence, and academic quality of the manuscript. Reviewed the final version of the paper and supported the refinement of the research presentation before submission.

7.2 acknowledgement
No additional acknowledgments are applicable.

7.3 Conflicts of Interest
The authors report no conflict of interest related to this work.

7.4 Institutional Review Board Statement
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7.5 Informed Consent Statement
Not applicable.

7.6 Data Availability Statement
The data that support the findings of this study are available from the corresponding author upon reasonable request. This study is based on a systematic review of previously published literature, and no new experimental or primary data were generated.

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