Design and Evaluation of a Multilingual Voice-Based E-Governance ICT Solution to Empower Non-Literate Citizens for Public Service Access

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Pakistan's rapid growth in mobile-phone and smartphone penetration has not been matched by a corresponding rise in the use of digital public services, largely because a substantial share of citizens, particularly in rural areas, remain non-literate or low-literate and cannot navigate text-heavy e-governance portals. This paper presents the design, development, and field evaluation of a multilingual, voice-based mobile ICT solution that lets non-literate and semi-literate citizens access core government services, including hospital information, police assistance, utility-complaint registration, subsidy inquiries, commodity price checking, and public transport information, through natural spoken interaction in Urdu, Punjabi, Hindko and Saraiki. Unlike prior text-free or fixed-menu voice interfaces, the proposed system embeds an artificial-intelligence-based intent-recognition and dialogue-management layer that allows a citizen to state a need using free-form conversational speech (for example, "I want to complain about electricity") and be routed automatically to the correct service and complaint workflow, without navigating nested menus. The system was designed using a six-phase User-Centered Design methodology comprising requirements gathering, an observational study, icon and voice-prompt assessment, prototype design, application development using Flutter, Firebase and Python-based AI services, and usability evaluation. A field study involving 45 rural participants aged 20–65 was conducted using ISO 9241-11 effectiveness, efficiency and satisfaction measures, comparing the proposed voice-based prototype against an existing text/menu-based e-government application. Results show substantially higher task-completion rates, shorter completion times and lower error rates for the voice-based system, together with a mean System Usability Scale score of 78.4, indicating good-to-excellent perceived usability. The findings support voice-first, AI-assisted design as a viable pathway toward digital and civic inclusion for non-literate populations in Pakistan and comparable developing-country contexts.

Keywords: E-Governance; Voice User Interface; Non-Literate Users; Digital Inclusion; Artificial Intelligence; Usability Evaluation; ICT4D; Pakistan

Introduction:

Over the past decade, Pakistan has witnessed a marked rise in mobile-phone and smartphone usage, and information and communication technology (ICT) has emerged as a potential enabler of inclusive public-service delivery. However, this technological progress has not been mirrored by a corresponding uptake of digital government services, particularly among citizens who lack confidence in reading and writing. The 7th Population and Housing Census reports that the overall literacy rate of Pakistan is around 60.6%, the male literacy rate is around 68% and the female literacy rate is around 52.8%, with a significant disparity between rural and urban areas, meaning that tens of millions of adults are unable to effectively use text-based digital interfaces [1].

This literacy gap adds to a wider digital divide in Pakistan, one shaped by urban–rural connectivity and infrastructure gaps, gender disparities in device access, income inequality, and gaps in policy implementation [2][3]. However, even if mobile connectivity is available, conventional e-governance interfaces can be hard to navigate because rural citizens and those of lower incomes may not have the reading skills, understanding of the English language, or previous experience with digital services assumed by these interfaces, and connectivity does not ensure meaningful access to services.

Despite the progress made in e-governance in Pakistan, there are several structural problems that are hampering the adoption of e-governance by citizens, such as inadequate ICT infrastructure outside metropolitan areas, low digital literacy among the rural population, an exclusive emphasis on English-language or written-Urdu user interface that excludes users who cannot read or write in English or Urdu, and the citizens' concerns about security and reliability of e-governance channels [4]. Comparative studies of the performance of e-government in Pakistan indicate that these are the main reasons for the relatively low position of Pakistan in the international e-government development index [4] and not the lack of policy intent.

Smartphone adoption in Pakistan has grown rapidly, including in rural households, yet most existing government mobile applications and web portals are designed around forms, menus and written text, implicitly assuming a literate, confident smartphone user. This creates a "last-mile" access barrier: the infrastructure to reach citizens exists, but the interface itself excludes a large proportion of the intended beneficiaries, particularly non-literate adults, older citizens, and women in rural households who report lower literacy and lower independent technology use [1][3].

Prior research has shown that text-free and icon-based interfaces can substantially improve task success for non-literate users in narrow domains such as mobile commerce and job search [5], and that interactive voice response (IVR) systems can improve information access for low-literate telephony users [6]. Isolated e-government pilots accessible to illiterate citizens have also been reported [7]. However, these efforts are generally built around fixed, hierarchical menu trees rather than free-form conversational interaction, are typically limited to a single domain or language, and do not span the breadth of core public services, health, law-and-order, utilities, subsidies, commodity prices and public transport that a rural Pakistani citizen may need in daily life. Regional languages beyond Urdu, including Punjabi, Hindko and Saraiki, remain particularly underserved by existing digital government tools. This gap between demonstrated feasibility in narrow domains and the practical breadth of everyday government interaction motivates the present study.

The specific objectives of this research are to:

- Design a multilingual, voice-based ICT solution that allows non-literate and semi-literate citizens to access core government services without requiring reading or writing ability.

- Enable AI-assisted, free-form spoken interaction so that a citizen's natural statement of need is automatically mapped to the correct government service and workflow, reducing dependence on rigid menu navigation.
- Enable end-to-end complaint registration and status tracking for utility and public-service grievances through voice interaction alone.
- Evaluate the effectiveness, efficiency and satisfaction of the proposed system with representative rural users using standardized (ISO 9241-11) usability measures, benchmarked against an existing text/menu-based e-government application.

Related Work:

ICT for Non-Literate Users:

Human–computer interaction research on illiterate and semi-literate populations has consistently shown that purely textual interfaces perform poorly for this group, whereas non-textual modalities such as graphics, icons, voice and video substantially improve task success. Text-free interfaces built through ethnographic design with illiterate communities have been shown to be strongly preferred over standard text-based designs and to bring otherwise inaccessible computer functions within reach of non-literate users [5]. Later controlled studies using text-based, graphical, and text and voice-based mobile interfaces with both novice and low-literacy users revealed that the non-textual options performed better than the text-only options, though each method has its own drawbacks, such as needing more scaffolding to accomplish the task with graphical interfaces and the potential for confusion with new domain-specific jargon with voice interfaces [8]. Based on this body of work, design guidelines were distilled to recommend that graphical cues, voice annotations, support for the local language, and simplified navigation and input be used as the basic principles of low-literacy interface design [9]. IVR systems based on natural speech (instead of touch-tone input) have also been found to facilitate information access for low-literate telephony users such as those in agriculture and health information [6][10].

E-Governance Systems:

The concept of e-governance is to transform public service delivery for citizens into a more efficient, transparent and accountable process through digitization. In the context of Pakistan, comparative analysis with more advanced e-government environments reveals that the relatively low level of e-government development is attributed to the lack of ICT infrastructure, lower rate of digital literacy in rural areas, the dominance of English- language and written-Urdu interfaces and citizens' lack of confidence in online transactions security [4]. These structural limitations contribute to the overall urban–rural divide as well as the divide between men and women and between rich and poor, which are documented in a general way across all cities [2][3] and which help explain the fact that a government mobile app or web portal does not necessarily lead to equitable citizen access.

Voice-Based Interfaces:

Voice user interfaces (VUIs) have evolved from touch-tone and recorded-prompt IVR systems to today's smartphone-based conversational assistants that can handle continuous speech and generate natural language responses. For non-literate users in particular, voice interface eliminate the need to read labels on menu options or type in queries, yet previous research warns that VUIs are not easy to make and can be problematic when the expected vocabulary set is narrow and the user can express their query in only one or a few preprogrammed ways [8][6][11]; background noise and unfamiliar terminology can also influence comprehension. This highlights the importance of using dialogue designs that are flexible with variations in the language used for a request, and not requiring any exact, scripted command.

AI-Assisted Public Services:

With government agencies worldwide turning to AI-powered conversational agents to respond to citizens' queries on taxes, licenses, permits, and social-welfare programs, the goal is to use natural-language processing to understand requests and walk citizens through multi-step processes, such as permit applications, from inquiry to completion [12][13]. These systems demonstrate that AI-based intent recognition and dialogue management can meaningfully reduce the navigational burden placed on citizens compared with static menu-driven portals. However, the great majority of deployed government chatbots and virtual assistants are text-based, delivered through web chat widgets or messaging applications, and implicitly assume that the citizen can read and type; voice-first, multilingual implementations aimed specifically at non-literate populations in developing-country contexts remain rare in the published literature.

Research Gap Analysis:

Synthesizing the above strands of literature reveals four gaps that motivate the present work. First, text-free, graphical and voice-interface research demonstrates feasibility for non-literate users but has mostly been validated in narrow domains such as commerce, job search or health-worker data entry, rather than across the breadth of everyday government services [5][8]. Second, the Pakistani e-governance literature documents literacy, language and infrastructure barriers in detail but tends to propose policy-level rather than interface-level solutions [4][2]. Third, AI-assisted government chatbots are expanding rapidly in other countries but are predominantly text-based [12]. Fourth, existing illiterate-accessible e-government pilots rely on fixed menu hierarchies rather than free-form conversational understanding, and regional languages beyond Urdu remain largely unaddressed [7]. No existing system, to the authors' knowledge, combines free-form multilingual voice interaction, AI-based intent recognition, and end-to-end complaint registration and tracking across the full span of core citizen-facing services, including health, law-and-order, utility complaints, subsidies, price information and public transport, for Pakistan's non-literate rural population. This gap is directly addressed by the design and evaluation presented in the remainder of this paper.

Research Methodology

This study follows a User-Centered Design (UCD) methodology, in line with the human-centred design principles for interactive systems set out in ISO 9241-210 [14], so that the resulting application reflects the actual vocabulary, mental models and usage habits of non-literate rural citizens rather than assumptions inherited from conventional, text-based e-governance design. The methodology is organized into six sequential phases, illustrated in Figure 1.

In Phase 1 (Requirements Gathering), semi-structured interviews were conducted with prospective citizen users, union-council representatives, and front-desk staff from hospitals, police help desks and utility (electricity, gas) complaint offices to identify the government services most frequently needed and the difficulties citizens currently face in accessing them. Phase 2 (Observational Study) involved contextual field observation of how target users presently use their mobile phones, including voice calls and voice-note messaging habits, to identify pre-existing voice-interaction behaviors and commonly used vocabulary that could inform the dialogue design. Phase 3 (Icon and Voice-Prompt Assessment) tested candidate icons and recorded voice prompts, in Urdu, Punjabi, Hindko and Saraiki, for comprehension with a small sample of the target population, and prompts or icons that were not reliably understood were revised. Phase 4 (Prototype Design) produced low-fidelity paper prototypes and Wizard-of-Oz-style voice-flow walkthroughs, in which a moderator simulated the system's spoken responses, to validate the overall conversational structure before any code was written. Phase 5 (Application Development) implemented the validated design as a working mobile prototype, described in Section 5. Phase 6 (Usability Evaluation) subjected the resulting prototype to a structured field study against ISO 9241-11 effectiveness, efficiency and satisfaction measures, described in Sections 6 through 9.

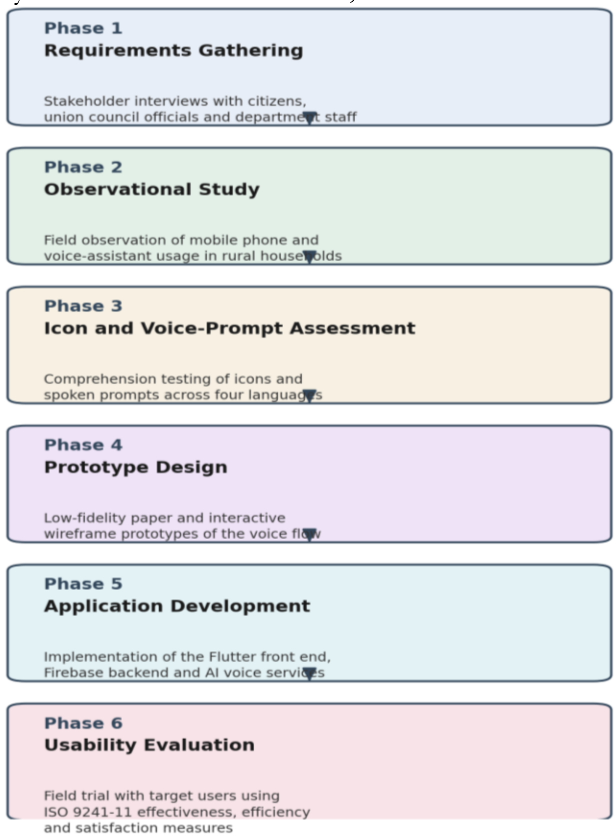

Figure 1. Six-phase User-Centered Design methodology adopted in this study**.**

System Design:

The system architecture (Figure 2) follows a layered design in which the citizen interacts primarily through speech and simple icon taps at the mobile-application layer, while an AI-based dialogue layer and cloud backend handle intent understanding, service routing, and persistent storage of citizen and complaint data.

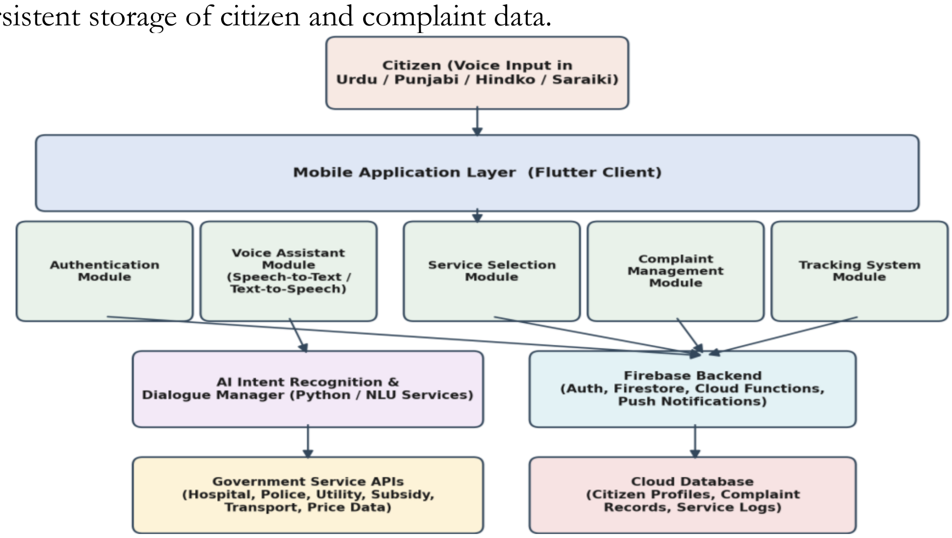

Figure 2. High-level system architecture of the proposed voice-based e-governance application.

Authentication Module:

To avoid password entry, the Authentication Module supports lightweight phone-number and one-time password (OTP) verification delivered by voice call or SMS read aloud by the assistant, with an optional CNIC-linked identity check for services that require eligibility verification, such as subsidy inquiries. This design choice follows established guidance to minimize text-based input and complex navigation for low-literacy users [9].

Voice Assistant Module:

The Voice Assistant Module captures the citizen's spoken utterance, performs automatic speech recognition using language-specific acoustic and language models for Urdu, Punjabi, Hindko and Saraiki, and forwards the resulting transcript to the AI dialogue layer. System responses and confirmations are converted back to speech using text-to-speech synthesis in the same language, so that no reading is required at any point in the interaction [15].

AI Intent Recognition and Dialogue Manager:

A Python-based natural-language-understanding service classifies each transcribed utterance into one of the supported service categories (hospital, police, utility complaint, subsidy, price checking, public transport) and, where required, a finer-grained sub-intent, such as distinguishing an electricity complaint from a gas complaint [16]. When information required to complete a request is missing, for example a meter number or locality, the dialogue manager conducts a short multi-turn, slot-filling exchange to collect it. This layer is designed to be extensible toward large-language-model-based understanding, which would allow the system to tolerate a wider range of unanticipated phrasings than a fixed intent-classification model [12], directly supporting the free-form interaction style illustrated in the electricity-complaint example in Section 1.

Service Selection, Complaint Management and Tracking Modules:

Service Selection Module will tell the user the matched service verbally for confirmation before it takes any further action, as this helps to avoid the risk of requests getting misdirected. The Complaint Management Module also converts a complaint into a standard record with a timestamp and tracking identifier and passes it to the departmental queue. The Tracking System Module enables a citizen to subsequently request – in their own words – the status of a previously entered complaint and receives a verbal status update based on the recorded information – without requiring the citizen to read a reference number or navigate a status page.

Database:

Citizen profiles, complaint records and service-interaction logs are stored on a cloud-hosted database, which both serves as a repository for the real-time processing of the application and provides the overall usage information shown in Section 8.

Implementation:

A working mobile prototype was created with the validated design from Phase 4, consisting of a cross-platform client (Android first due to the dominance of these platforms among the target population) and a cloud backend with a set of Python-based AI services.

Development Tools:

The mobile client was developed in Flutter, making it possible to develop applications for Android and (potentially) iOS from a single codebase and support the custom widgets with minimal text used in the interface [17]. Authenticating and implementing of backend services, including the Firestore document database, server less cloud functions for complaint routing, and push notifications for status updates, were performed using Firebase [18]. Speech recognition, TTS, and the AI intent-recognition and dialogue-management logic outlined in Section 4.3 were realized as Python-based AI services that were provided to the Flutter client via REST APIs, which enabled their update and retraining without having to modify the mobile app.

Conceptual Interface Design:

Consistent with the low-literacy design guidelines discussed in Section 2.1, the interface was built around three principles: (i) all primary input is voice, with single-tap icon shortcuts as a secondary channel; (ii) every icon is paired with a short-spoken label so that comprehension never depends on reading text; and (iii) any information displayed on screen, such as a complaint status, is also available as a voice read-back on request. Figure 3 presents conceptual wireframes of the three principal screens: a home screen combining a prominent microphone control with icon shortcuts for the most common services, a voice-assistant screen showing the live conversational exchange together with confirm, repeat and cancel controls, and a complaint-tracking screen presenting a color-coded status timeline that the citizen can also have read aloud.

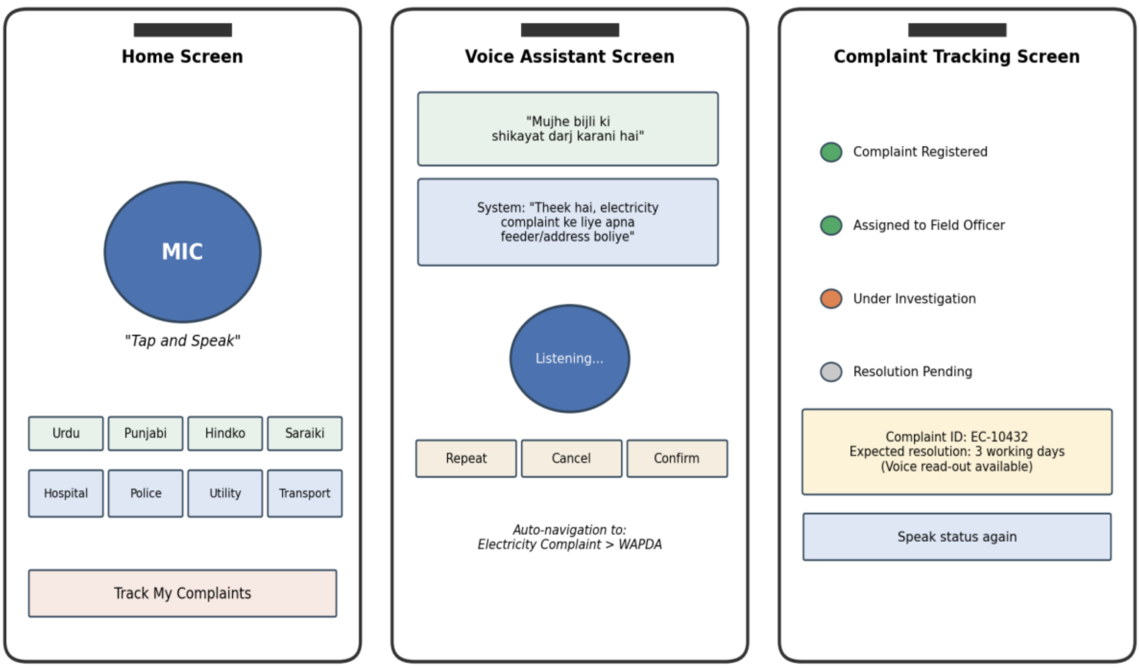

Figure 3. Conceptual UI mockups of the (a) home screen, (b) voice assistant screen, and (c) complaint tracking screen produced during the prototype design phase.

The worked example in Figure 3(a,b,c) mirrors the scenario introduced in Section 1: rather than navigating a menu hierarchy, the citizen states "Mujhe bijli ki shikayat darj karani hai" ("I want to register an electricity complaint"), and the AI dialogue manager both identifies the correct service and initiates the slot-filling exchange needed to complete the complaint, illustrating the core novelty of the proposed system relative to fixed-menu voice or IVR designs [7][5].

Experimental Setup:

Participants:

In total 45 participants were purposively sampled from rural union councils in Punjab Province and Khyber Pakhtunkhwa Province in Pakistan, as a mix of Punjabi, Hindko and Saraiki speakers as well as Urdu speakers. Participants aged 20 to 65 years were selected based on the literacy status ranging from non-literate to low-literate adults, following the census definition of literacy.[1] Recruitment took place through contacts within communities and in the union-council and informed consent was obtained orally and read aloud by the moderator before participation. Demographic information of the participants is presented in Table 1.

Table 1. Participant demographics (N = 45).

Characteristic	Category	n	%
Gender	Male	24	53.3
	Female	21	46.7
Age group (years)	20–35	16	35.6
	36–50	18	40.0
	51–65	11	24.4
Preferred language	Urdu	14	31.1
	Punjabi	15	33.3
	Hindko	9	20.0
	Saraiki	7	15.6
Prior smartphone use	Regular user (calls/voice notes)	33	73.3
	Infrequent/first-time user	12	26.7

Tasks:

Each participant performed three representative tasks: (T1) Locating a specific service, such as the nearest hospital and checking subsidy eligibility; (T2) Registering a complaint for a utility service, either electricity or gas; and (T3) Following up a complaint previously made for a utility service. The order in which tasks were presented was counter-balanced across participants to control for learning effects.

Procedure:

Sessions were held in participants' home localities to simulate real life conditions with respect to network connectivity and background noise. Each session included a short verbal explanation of the system, and task attempts were performed using a think-aloud protocol. Task completion, completion time and any errors that resulted in errors requiring correction were recorded by a moderator, who did not offer task-solving assistance unless the participant was no longer able to complete the task, in which case, the attempt was recorded as a failure. Following the use of both the systems, the moderator read out the ten items of System Usability Scale (SUS) questionnaire orally and explained the five-point response scale with the help of a finger-counting analogy in the language of choice of the participant [19].

Evaluation Metrics:

Usability was assessed using the three dimensions defined in ISO 9241-11, effectiveness, efficiency and satisfaction, which together characterize the extent to which specified users can achieve specified goals in a specified context of use [20][10].

Effectiveness:

Effectiveness was operationalized as the task completion rate, the percentage of task attempts completed successfully without moderator intervention, and the error rate, the proportion of attempts containing at least one navigation, comprehension or misrouting error.

Efficiency:

Efficiency was measured as the mean task completion time in seconds, recorded from the point the participant received the initial system prompt to the point the task was confirmed complete. [21]

Satisfaction:

Satisfaction was measured using the System Usability Scale (SUS), a widely used ten-item, five-point Likert questionnaire yielding a single score between 0 and 100, computed using Brooke's standard scoring procedure [19]. Scores were interpreted against the commonly cited benchmark average of approximately 68, with scores above this threshold generally considered above-average usability [19].

Results and Discussion:

Figure 4 summarizes the results across the three evaluation tasks (T1: access service, T2: register complaint, T3: track complaint), comparing the proposed voice-based prototype against the existing text/menu-based baseline application.

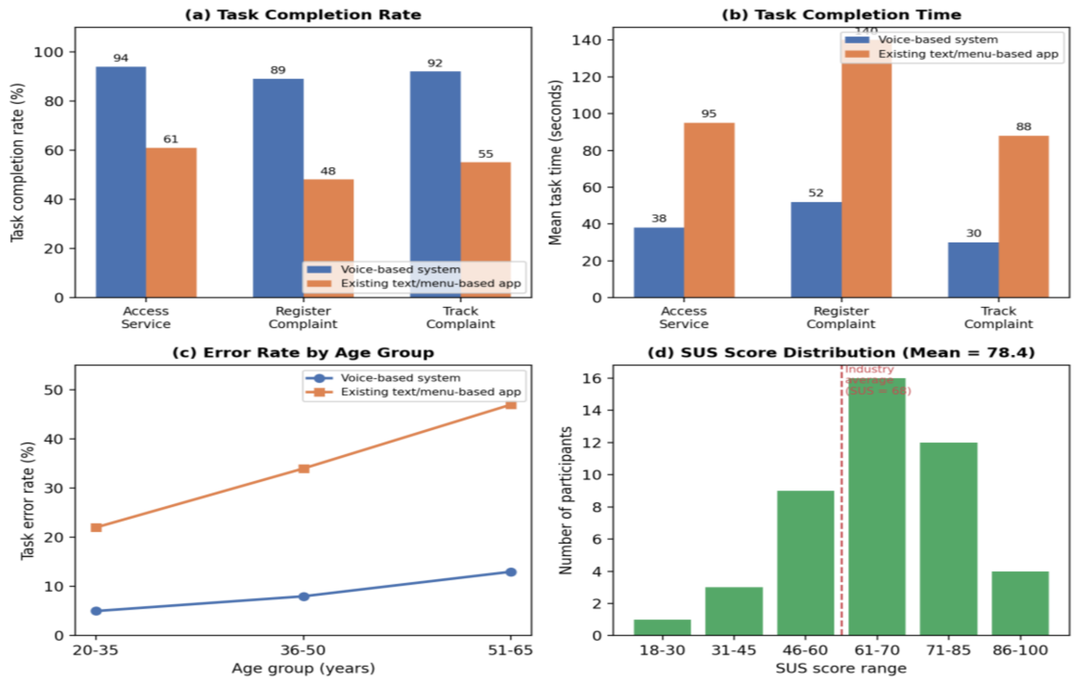

Figure 4. (a) Task completion rate, (b) task completion time, (c) error rate by age group, and (d) SUS score distribution.

Effectiveness:

As shown in Figure 4(a), the voice-based prototype achieved task completion rates ranging from 89% to 94% across the three tasks, compared with 48% to 61% for the existing text/menu-based application. The performance deficit was largest for T2, the most information-intensive task, indicating that the AI-assisted slot-filling dialogue from Sections 4.1–4.3 was most effective at supporting participants in completing a multi-step process that was difficult for non-literate users to navigate through the nested menus and text input boxes of the baseline application. Figure 4(c) also shows that the proportion of errors made by the participants on the baseline application rose from 22% to 47% for the 20–35-year-old and 51–65-year-old groups respectively, while the proportion of errors made on the voice-based prototype rose from 5% to 13% for the same age bands. This trend suggests that the voice-first approach helps to bridge, albeit not completely resolve, the digital-service access divide between generations as seen in earlier work showing that the use of non-textual modalities decreases barriers for users who have less prior experience with digital services [8].

Efficiency:

As seen in Figure 4(b), the mean task completion times were always lower for the voice-based prototype (30–52 s) than for the baseline application (88–140 s). The biggest time saving was again found with complaint registration, with the AI dialogue manager's guided, conversational slot-filling mitigating the repeated back-and-forth through menus seen by several of the participants when using the baseline application's hierarchical structure.

Satisfaction:

The mean SUS score for the voice-based prototype was 78.4 (Figure 4(d)), which is generally considered to be in the "good to excellent" range, and well above the widely quoted benchmark average of approximately 68 [19]. The distribution in Figure 4(d) reveals that the majority of participants rated the system in the 61-85 range with a smaller number of very high (86-100) ratings and a smaller number of moderate (31-60) ratings, representing broadly consistent but not uniform satisfaction across the sample.

Discussion:

Such findings corroborate and add to previous evidence that non-textual modes of interaction have a positive effect on task success for low-literacy populations [8][5][22]. The main novelty of the present study is the possibility to use multilingual voice input and to use AI-based intent recognition across abroad range of core government services – not only for one particular domain, nor following a fixed menu hierarchy as in previous illiterate-accessible e-government pilots [7]. This was confirmed by qualitative observation during the sessions. In most cases, a request phrased as a natural sentence, like the electricity-complaint example in Section 1, was navigated correctly on the first try, while similar requests on the baseline application often required two or more steps in the menu and several older participants gave up on even getting to the correct screen.

These findings should be interpreted in light of several limitations. First, the evaluation was conducted as a moderated field study rather than a fully autonomous, longitudinal deployment, so completion rates and times may differ once the system is used without any moderator presence. Second, while the sample of 45 participants is consistent with typical usability-evaluation sample sizes and adequate for the descriptive comparisons reported here, it does not support strong inferential generalization to Pakistan's rural population as a whole. Third, the field trials were conducted under normal rural connectivity conditions but did not systematically stress-test the system under prolonged network outages, which are common in some rural areas and motivate the offline-mode extension discussed in Section 9.

Conclusion and Future Work:

This paper has presented the design, implementation and field evaluation of a multilingual, AI-assisted, voice-first mobile application aimed at giving non-literate and semi-literate citizens practical access to core government services, including hospital information, police assistance, utility-complaint registration, subsidy inquiries, price checking and public transport, through natural spoken interaction in Urdu, Punjabi, Hindko and Saraiki. Using a six-phase User-Centered Design methodology, the system was developed to allow citizens to state a need in free-form speech and be automatically routed to the correct service and complaint workflow, rather than navigating fixed menus. A field evaluation with 45 rural participants, using ISO 9241-11 effectiveness, efficiency and satisfaction measures, found substantially higher task completion rates, lower completion times and lower error rates relative to an existing text/menu-based e-government application, together with a mean SUS score of 78.4. These results suggest that voice-first, AI-assisted design is a viable and measurably effective pathway toward digital and civic inclusion for non-literate populations in Pakistan.

Future work will extend the system in four directions. First, an offline mode will be developed to cache common prompts and defer synchronization of complaint records when network connectivity is unavailable, addressing the connectivity limitation noted in Section 8.4. Second, language coverage will be expanded to additional regional languages such as

Pashto, Sindhi and Balochi, broadening access beyond the four languages evaluated in this study. Third, the AI intent-recognition and dialogue-management layer will be upgraded with larger, locally fine-tuned speech-recognition and language models, including exploration of on-device inference to reduce latency and data cost for users with limited mobile data budgets. Fourth, a larger-scale, longitudinal deployment conducted in partnership with the relevant government departments will be pursued to evaluate the system's performance in unmoderated, real-world use and to integrate it directly with departmental complaint-resolution pipelines, along with accessibility extensions to better support visually impaired citizens.

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