ASAN MANDI: Digital Transformation of Pakistan's Fruit and Vegetable Market

Ameer Jan, Zartasha Baloch, Madeha Memon, Aisha Manzoor, Tanzeel Ahmed
Department of Computer Systems Engineering, Mehran University of Engineering and Technology, Jamshoro, Pakistan.
* Correspondence: zartasha.baloch@faculty.muet.edu.pk

Pakistan's agricultural sector, particularly its traditional Mandi markets, suffers from inefficiencies due to manual processes that result in time delays & data inaccuracies. ASAN MANDI is a mobile application to automate & centrally manage data for improving productivity, transparent transactions, and profits for farmers and traders. The app is developed using cross-platform technology (Flutter) and integrated primary modules, including electronic billing (e-billing), digital ledger management, real-time inventory tracking system, etc. All testing was conducted on devices with varying specifications to ensure app usability, interface consistency, and the effectiveness of urban and rural study devices. Results highlighted the reductions of manual errors made, time and effort in transaction processing and inventory management, with 88% of users asserting satisfaction towards the intuitiveness of app design as well as bilingual support (Urdu and English). Nonetheless, network dependence in remote regions and user adjustment were some challenges to be addressed in the future. To summarize, ASAN MANDI is a useful platform to address the issues being faced in conventional agricultural markets of Pakistan and could be a role model for other developing economies striving to improve their agricultural productivity.
Keywords: ASAN MANDI; Digital Agriculture; Mandi Mobile App; Fruit and Vegetable Market; E-Billing; Inventory Tracking

Introduction:

Pakistan's agricultural sector plays a vital role in the national economy; however, it remains hindered by inefficiencies stemming from traditional, manual marketplace systems such as Mandi. These outdated systems frequently result in time delays, inaccurate data handling, and financial losses for both farmers and commission agents. There is high potential for transforming the traditional farming landscape into a digital marketplace, empowering millions of smallholder farmers. The digital platforms for crop pricing, supply chain management, and direct farmer-to-consumer marketplace can make the agriculture sector more transparent and profitable. This helps farmers to access real-time information about the needs of consumers to make informed decisions about crop selection and cultivation.

In a typical Mandi setup, products are brought in by farmers and displayed for potential buyers. Transactions are often conducted through in-person negotiations and manual record-keeping, which often leads to inefficiencies and inaccuracies. Key aspects of Mandi operations include manual billing, inventory management on physical ledgers, and dependency on intermediaries for handling financial transactions. This reliance on paper-based records results in frequent delays and susceptibility to errors or loss of data. Furthermore, Mandi environments are subjected to climatic and seasonal conditions, with variables such as temperature, humidity, and pressure influencing the timing and quality of produce brought to the market. For instance, during peak harvest seasons or under specific weather conditions, the influx of produce can overwhelm the Mandi system, leading to challenges in record-keeping and inventory management. The selected Mandis in this study are situated across various regions of Sindh, Pakistan. Figure 1 shows the traditional workflow of the Mandi process.
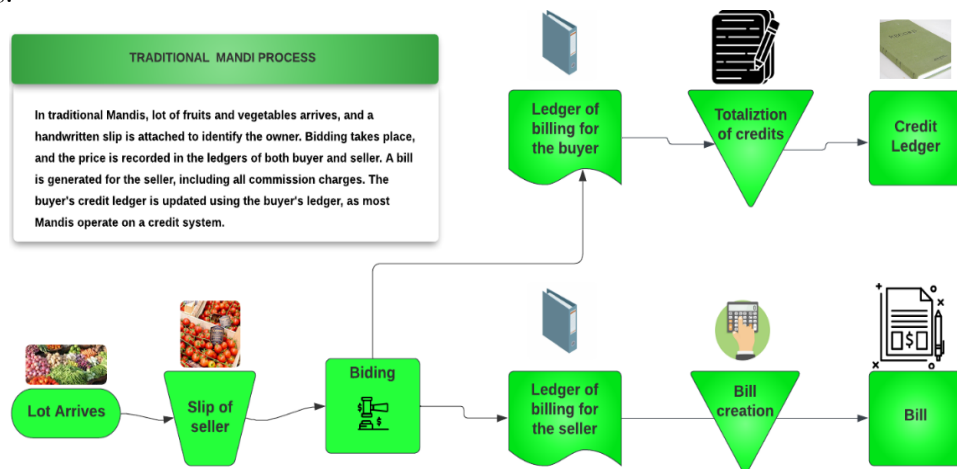

Figure 1. Traditional Agricultural Mandi Workflow

Despite the well-researched potential of digital agricultural marketplaces to enhance supply chain efficiency, such as reducing intermediary exploitation, improving transparency, and increasing farmers' profitability, their adoption in Pakistan's traditional agricultural mandi ecosystem remains critically low. Existing literature identifies key barriers, including financial constraints, inadequate digital infrastructure, and low literacy rates among rural users. There is an urgent need for an intuitive digital platform that empowers farmers by minimizing intermediary dependencies, ensuring fair pricing, and streamlining direct market access. Recent advancements in mobile and web-based technologies offer accessible, cost-effective solutions that can be tailored to the specific needs of agricultural marketplaces.

Related Work:

Technology plays a significant role in increasing productivity, especially in sectors like healthcare, education, agriculture, and industrialization, where factors such as the high cost of adoption, privacy issues, and change obsolescence are barriers [1]. The Small and Medium

Enterprises (SME) in Pakistan are improving their performance using the latest technologies such as the Internet of Things and social media. Author[2] explore the impact of digital technologies such as social media, big data analytics, IoT, blockchain, and artificial intelligence on the economic and social value creation of Pakistani SMEs. They collected survey responses from 305 SME managers for analytics using Structural Equation Modeling (SEM) and Artificial Neural Networks (ANN). The analysis results indicate that social media, big data analytics, IoT, and blockchain are the most value-adding aspects, while AI-based applications are rarely used [2]. Author[3] explore the development of E-Mandi, an electronic vegetable market platform to remove middlemen and guarantee fair price guaranteeing. It is a web-based fruit and vegetable market that seeks to improve the effectiveness and transparency of the market by connecting everyone directly. Some of the advantages of E-Mandi include the decreasing level of wastage during transport of goods for sales, reducing the level of farmers in the hand of the middlemen, avoid some of the factors of the black market, effecting price controls where necessary, increasing the level of price friendly competition in the markets and standardizing of price. The Indian agricultural sector is also characterized by several limitations, which include low productivity and viability, poor infrastructure, and poor competitive rivalry off-farm. Agriculture is marketed traditionally through haats, shandies, and mandis, where the farmers bring their products to sell [4]. The Indian government started the E-NAM [5] program to bring together agricultural commodity markets across India. It links various physical markets (Mandis) through an online platform. The program aims to create a marketplace for trading agricultural products that is efficient, transparent, and competitive. E-NAM faced many challenges, including a lack of technical expertise among farmers, bargaining dynamics between farmers and middlemen, infrastructural constraints, and post-harvest quality assessment [6][7][8][9]. The success of digital marketplaces relies on effective collaboration between consumers and middlemen, ensuring smooth transactions, trust, and mutual benefit for all stakeholders involved [10]. The essential fields for effective agricultural marketplaces are identified as market and opportunity, resources, and entrepreneurial team [11].

With digitalization emerging as a key driver of economic growth, improving the efficiency of agricultural marketplaces has become a major priority for stakeholders aiming to modernize and transform the sector. Inspired by the impact of digital agricultural platforms, the proposed ASAN MANDI mobile application aims to streamline Pakistan's agricultural marketplace by digitizing essential processes such as billing, inventory management, and transaction recording, thereby offering a solution tailored to local challenges.

Objectives:

The following objectives serve as novel contributions of this research:

To provide a digital solution for Mandi transactions that replaces manual processes with automated systems, aiming to increase accuracy and reduce errors.

To provide a digital ledger for precise tracking and recording of transactions, minimizing data loss, and improving financial management for commission agents and traders.

To provide an e-billing system that allows for quick and accurate billing, replacing traditional manual invoices and streamlining the transaction process.

To provide real-time inventory management features that enable commission agents to efficiently monitor stock levels, optimize supply chain decisions, and reduce wastage.

To provide support for the local language (Urdu, along with English) to ensure accessibility and ease of use for all users, regardless of literacy or technical proficiency.

Novelty Statement:

This research designs and develops a mobile application, ASAN MANDI, as a digital marketplace tool, evaluating its potential to address existing challenges and improve market efficiency by providing e-billing, inventory management, and transaction recording services.

Material and Methods:

Digital solutions like ASAN MANDI aim to address these systemic inefficiencies by introducing real-time data tracking, electronic billing, and automated inventory management. Figure 2 shows the proposed conversion of the traditional mandi system in the digital mandi. The study's focus is to highlight the critical role of mandi in Pakistan's agrarian economy and emphasizes the need for a streamlined, digitized marketplace to support sustainable and improved market accessibility for all stakeholders.
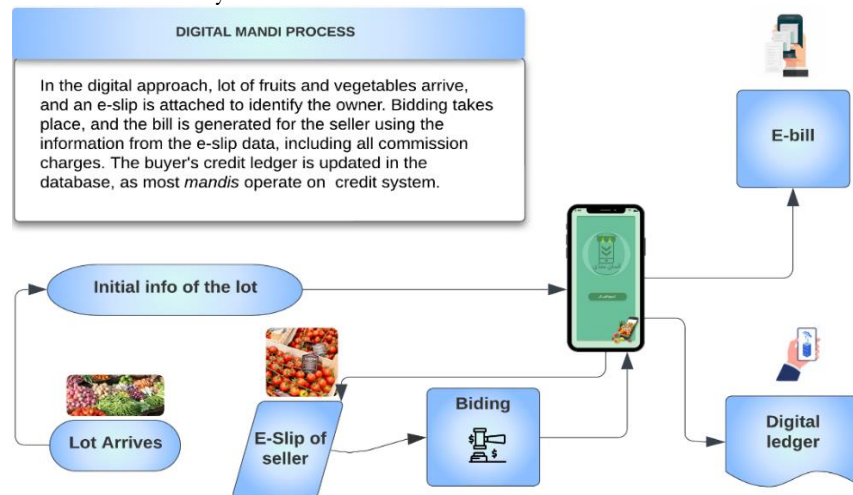

Figure 2. The Proposed Digital Agricultural Mandi Process

Technologies Used:

The Asan Mandi mobile application was developed with the Dart programming language; Flutter is a cross-platform mobile development framework that allows the app to run swiftly on both Android and iOS platforms with minimal code changes. The Firebase was used for backend operations to enable real-time data updates, cloud storage, and user authentication while providing smooth interactions throughout the application. Cloud store options include Firebase Realtime Database or Firestore Cloud Data Store, which allow for instant updates to users but require a back-end server to send data. We used SQLite for local data persistence, which allows users to access important data even when there is no internet connection available. Secure user sign-ins and registration are managed by Firebase Authentication to ensure privacy and security. The app interface was designed using Figma, which helps to prototype and map out how the overall app components work together. In addition, Firebase Cloud Storage was used for the management of media files (images and videos) with user references to ensure scalability.

Flowchart:

Figure 3 shows the flowchart of the Asan Mandi App that provides a comprehensive overview of activities in the process, making it possible to depict the order of actions, decisions, and the direction using symbols and lines.

The process begins with the selection of language, allowing users to choose either Urdu or English as the interface language. Then comes new user registration or user login. Upon successful login, users are directed to the main interface, which displays four key submodules: Initial List, which allows users to add items and create a list of products available in the inventory. Billing enables users to generate and print bills for customers. It includes options for adjusting totals, discounts, and additional charges. Ledger keeps track of financial records, including past transactions and due balances, allowing users to manage and view customer dues. Connections manage customer and supplier connections, providing options to add new contacts and link them to transactions within the system. Within each submodule, users can perform different tasks of the mandi.

Functional Design:

This section explores various aspects of the functions, focusing on how they are currently designed, developed, and implemented. Figure 4 and Figure 5 show the user interfaces for each function of the app. The description of each function is given below.
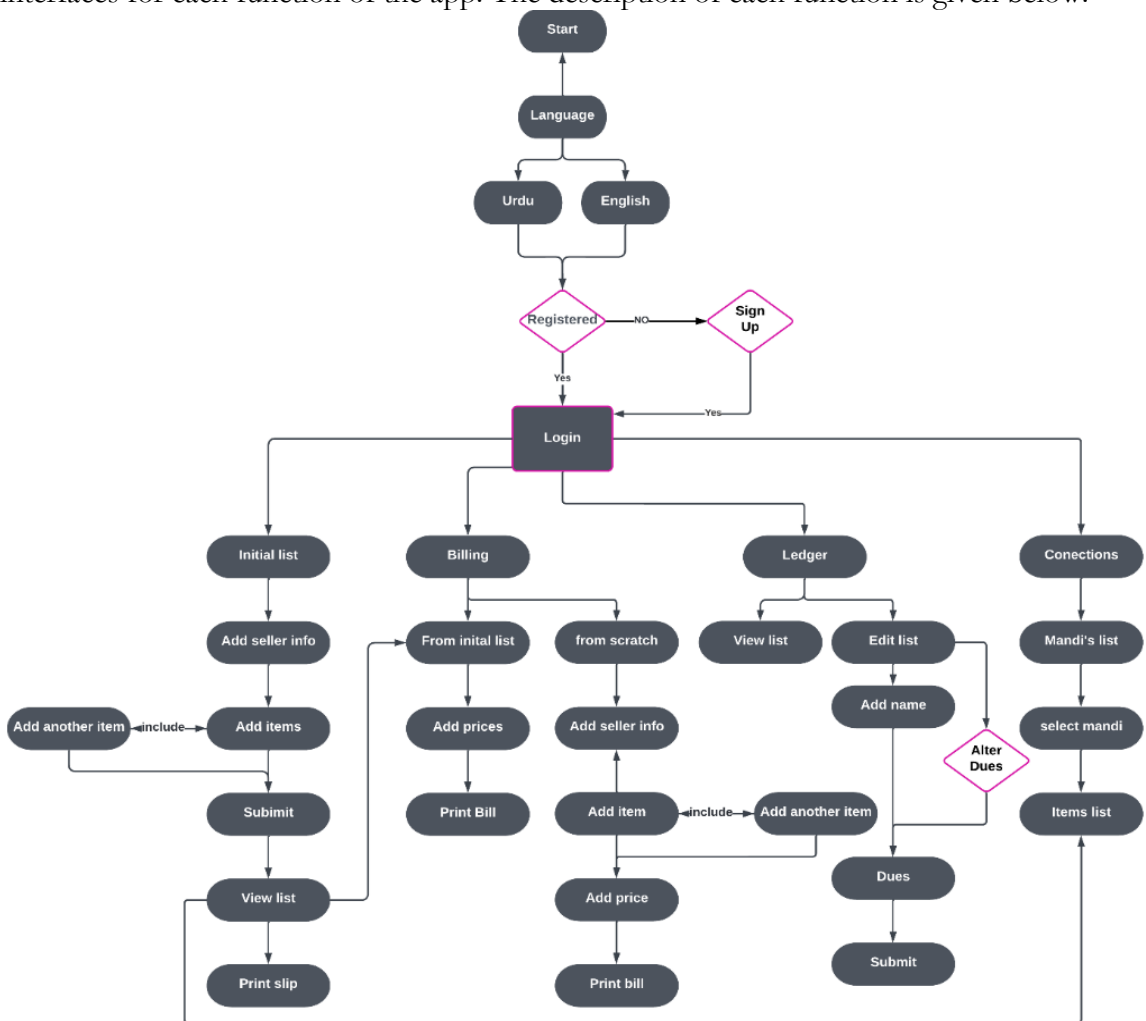

Figure 3. Flowchart of ASAN MANDI App

Figure 4. Item Listings on ASAN MANDI App (a) Home screen (b) Initial List (c) View Initial List (d) Billing

Home Screen:

The main menu screen serves as the central navigation hub, providing four primary options: Billing, Initial List, Connections, and Records. These options are similar to the manual flow of traditional mandis. These choices are accessible as icons with Urdu labels, which enable users to navigate around the app according to their needs.

Initial List:

The screen named "ابتدائی فہرست" (Initial List), which shows a form for inserting an item/entry to the marketplace. It has provisions for username, item name, container type, item count, and rent porterage cost. At the bottom, three buttons are given for adding a new item, submitting the form, or viewing the current list of items.

View Initial Listing:

The list is arranged in tabular form. The first column represents the names of people or suppliers (e.g. امیر جان), the second column shows the names of items (e.g., سیب (Apple), ناشتائی(Pear)). Lastly, the third column displays the type of container, e.g., ڈبہ or Box.

Billing Screen:

Then comes the billing options screen, where the user can create a new bill or make a bill from the existing list. The "شروع سے بنائیں" (Start Billing) button creates a new bill from scratch, while the "ابتدائی فہرست سے بنائیں" (Create from Initial List) button makes it easy for the user to use the saved data. Vendors seeking quick and efficient invoice generation benefit from the flexibility offered by the billing options.

Figure 5. Billing interfaces of Asan Mandi Mobile App (a) Bill from scratch, (b) Bill Creation from Initial List, (c) Bill Receipt, (d) Ledger

Bill From Scratch:

The screen on which the user can create a bill from scratch. It shows the text fields to input customers' names and other specific information, such as porterage (handling costs) and rent. There is another option to select an item from a drop-down list, select the container type, and enter the item rate and price. After filling in the required data, the next step is to click on the "بل بنائیں" button to create the bill. After that, more items can be added to the bill using the "اور شئ شامل کریں" (Add Another Item) button.

Bill Creation from Initial List:

This screen illustrates the process of bill creation for a customer, Ameer Jan, in this case, from the previous list. The billed item was سیب (Apple), in a ڈبہ (Box) unit, and the number of items was 5. This made it easy for the user to replicate the details into a bill template since the price, additional charges, and total cost were already filled in. The screen displayed 500, 50, and 100, which represented per-item cost, the packing charge, and other miscellaneous charges, respectively. After entering all the data from the first list, they could click on the 'Create Bill' button at the bottom of the screen.

Bill Receipt Screen:

After the creation of the bill, a screen appears to show the receipt. The example screen displayed in Figure 5 (c) shows a transaction record of Ameer Jan, where he sold 5 boxes of apples. The total bill subtracts different expenses from the amount for apples. At the bottom of the screen, there are two buttons: one for printing a copy of the receipt and the other for sharing it with others.

Ledger Screen:

This is another one from an accounting or bookkeeping type of Urdu app. At the Top, the Title is "کھاتہ": "Account" Or "Ledger" area for financial records. The image at the center displays of person with a computer on invoices, and a calculator, thus representing the working accounting activities. Which would leave them with two options. The first one is ریکارڈ دیکھیں (View Records) that helps the user to view his/her records of payments. The second option, Edit Records, allows you to change or update some records. This screen provides a simple and intuitive interface for the management and review of ledger and financial information.

Ledger Viewing and Editing:

The screen shows a record in the mobile App, written in Urdu 'ریکارڈ دیکھیں' meaning View Record. It shows the names and total amount for the customers who bought items from the mandi. Two options are presented at the bottom. The first option [نیا شامل کریں] is used to insert a new record, and the second one [محفوظ کریں] is responsible for saving the existing record. The interface is designed to manage financial records, where one can view or add entries of the buyers.

Use Case Diagram:

The use case diagram has a graphical representation of user interactions in the system in the case of the Asan Mandi App, as shown in Figure 6. It begins with the choice of language (either Urdu or English), then moves on to registration/login. When logged in, users can manage the pre-filled list by inputting information on the seller, the items, and by viewing lists and printing out slips. The payment and subscription feature allows for pricing, bill management, and printing of bills. The ledger management also entails activities such as viewing/editing lists, naming some of them, and altering amounts due. The connections allow the users to select a mandi, view their lists of mandis, and do the related work. Extension points display additional activities within the application, such as adding items or printing item details, providing insight into the app's overall functionality.

Result and Discussion:

The study was conducted in Hyderabad, Sindh, to assess user satisfaction and digital mandi adoption potential. Using purposive sampling, 20 participants were surveyed using dichotomous (yes/no) questions.

User Testing and Feedback:

The user-testing phase simulated interactions as if ASAN MANDI were integral boards across many mobile devices at the same time. The goal was to check the user experience, functionality, and usability. The testing aimed to evaluate user satisfaction, navigation ease, feature accuracy, and overall performance. Structured surveys were designed carefully to gather feedback in areas like ease of use, navigation clarity, language accessibility, billing accuracy, and inventory tracking.

In the final survey, users reported high satisfaction levels, with 88% finding the interface intuitive and easy to navigate. The app's bilingual support was appreciated by 92% of users, as it made it more accessible for a wider audience. E-billing feature received valuable feedback for its speed and accuracy, quickly enabling users to generate invoices accurately under their names. Real-time inventory tracking was another focal point in testing, with 82% of users feeling it improved understanding of supply. Some traders found it challenging to

move from a manual to a digital system. Additionally, the performance of the app in areas where the internet connection was unstable suffered noticeably, affecting overall usability.
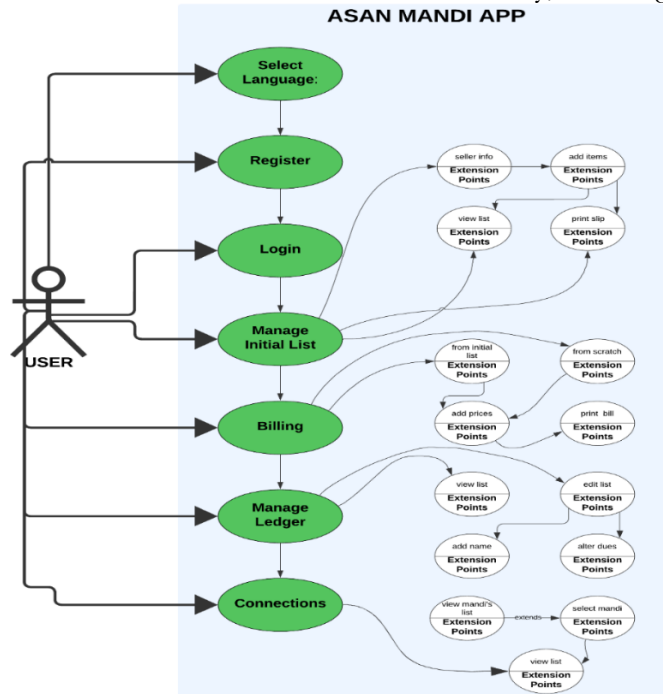

Figure 6. Graphical Representation of User Interactions in the ASAN MANDI App

Table 1. User Testing and Feedback

Feedback Category	Positive Response (%)	Negative Response (%)	Key Comments
Ease of Use	88%	12%	Most users found the interface intuitive.
Navigation	85%	15%	The menu structure was clear and concise.
Language Accessibility	92%	8%	Bilingual support was highly appreciated.
Billing Accuracy	87%	13%	Minimal errors reported in e-billing.
Inventory Tracking	82%	18%	Improved stock visibility.

The results from Table 1 seem to indicate that the ASAN MANDI app serves digital Mandis well with improved efficiency, accuracy, and scalability. By enhancing connectivity and offering essential user training, broad adoption and sustained high levels of usage will be achieved.

Behavior Testing:

Behavior testing was conducted on multiple devices and operating systems for compatibility, response, and uniformity. The result is summarized in Table 2.

The app maintained uniform UI appearance across all platforms, with buttons, menus, and forms all displaying properly. There was a small difference in loading time on different devices, with newer versions being quicker.

Functional Testing:

Functional testing confirmed that the key features of the system were accurate and stable. It was capable of handling high transaction volumes while maintaining low error rates. This involved testing core components of the ASAN MANDI app, such as user registration, e-billing, digital ledger management, and stocks management. For each feature, accuracy, stability, and error handling capabilities were evaluated individually.

Table 2. Behavior Testing

Device/Platform	Loading Time	UI Consistency	Control Functionality	Overall Usability
Android 9.0	2.8 seconds	Consistent	Smooth	Good
Android 10.0	2.5 seconds	Consistent	Smooth	Good
Android 11.0	2.3 seconds	Consistent	Smooth	Excellent
Android 12.0	2.1 seconds	Consistent	Smooth	Excellent
iOS 12.0	3.0 seconds	Consistent	Responsive	Good
iOS 13.0	2.7 seconds	Consistent	Responsive	Good
iOS 14.0	2.5 seconds	Consistent	Responsive	Excellent

User Registration Test Results:

The user registration process was assessed to ensure secure account creation and login are supported. The test results are summarized in Table 3.

Table 3. User Registration Test Results

Test Case ID	Description	Input Data	Expected Outcome	Actual Outcome	Status
URT-01	Enter valid details	Valid email, phone	Account created successfully	Account created	Passed
URT-02	Enter an invalid email format	Invalid email	Error message displayed	Error message	Passed
URT-03	Duplicate registration	Existing email	Error message displayed	Error message	Passed
URT-04	Password reset functionality	Valid email	Password reset email sent	Reset email sent	Passed

It had high accuracy in the user registration component and therefore oversaw both valid and invalid inputs correctly.

E-billing System Test Results:

For the e-billing system, testing focused on its ability to construct accurate invoices, error handling, and the registration, customer relationship management process.

Table 4. E-Billing System Test Results

Test Case ID	Description	Input Data	Expected Outcome	Actual Outcome	Status
EBT-01	Generate e-bill	Item details	E-bill generated successfully	E-bill generated	Passed
EBT-02	Invalid item entry	Invalid item code	Error message displayed	Error message	Passed
EBT-03	E-bill cancellation	Cancel command	E-bill canceled successfully	E-bill canceled	Passed
EBT-04	Retrieve e-bill	Invoice ID	Correct e-bill displayed	Correct e-bill	Passed

The e-billing system was unchanged in functionality during testing, maintaining reliable invoice management and handling errors accurately.

Digital Ledger Management Test Results:

Digital ledger management testing was concerned with an application's capacity to function properly while creating, updating, and retrieving transaction data. The results are shown in Table 5.

The testing of the digital ledger showed that it consistently maintained high accuracy, enabling users to manage accounts effectively.

Inventory Tracking Test Results:

Inventory tracking was designed to ensure accurate stock management from addition or deletion to changing the size of an item.

Table 5. Digital Ledger Management Test Results

Test Case ID	Description	Input Data	Expected Outcome	Actual Outcome	Status
DLT-01	Add a ledger entry	Transaction details	Ledger entry added	Entry added	Passed
DLT-02	Update the ledger entry	Updated data	Ledger entry updated	Entry updated	Passed
DLT-03	Retrieve the ledger entry	Transaction ID	The correct ledger entry is displayed	Correct data	Passed
DLT-04	Invalid transaction entry	Invalid details	Error message displayed	Error message	Passed

Table 6. Inventory Tracking Test Results

Test Case ID	Description	Input Data	Expected Outcome	Actual Outcome	Status
ITT-01	Add new stock	Item details	Stock added successfully	Stock added	Passed
ITT-02	Update stock	Item ID, quantity	Stock updated successfully	Stock updated	Passed
ITT-03	Remove stock	Item ID	Stock removed successfully	Stock removed	Passed
ITT-04	Generate an inventory report	Stock data request	Accurate report displayed	Accurate report	Passed

There is broad support for inventory Tracking among agricultural establishments, as it enables real-time monitoring of goods delivery and allows them to conduct their stock checks when needed.

Performance Testing:

Performance testing included app response time, load accommodation capabilities, and stability under high transaction volumes.

Table 7. Performance Testing Results

Functionality	Avg. Response Time	Max Load Capacity	Error Rate	Observations
Registration	2 seconds	500 users	0%	Stable across simulated load
E-Billing	1.5 seconds	1,000 transactions	0.2%	Minor delay under peak loads
Digital Ledger	2.2 seconds	1,200 entries	0.3%	High accuracy with minimal errors
Inventory Tracking	1.8 seconds	1,000 items	0%	Consistent performance

The app maintained low response times and high stability, indicating its readiness for large-scale applications. However, minor delays when under stress may suggest areas of performance optimization that deserve attention.

Discussion:

Internal assessments of the ASAN MANDI application highlight its prospects for efficiency enhancement in mandi operations. The app's primary strengths reside in its automation, accuracy of the financial operations, and up-to-date inventories. All these features improve the operations of the mandis by enhancing the transaction time and decreasing the

instances of errors that are made manually. The application is the center of all the mandi activities, hence enhancing transparency and accuracy of transactions to avoid financial losses and enhance real-time information provision for timely decision making. Additionally, mandi operators are consistently updated about stock volumes, which improves stock control and management and minimizes the risk of stock out or stock piling.

The Punjab government of Pakistan developed a digital platform, Agricultural Market Information System (AMIS) Pakistan [12], that provides real-time price updates for crops, vegetables, and fruits from over 100 major markets of Punjab province, but it lacks transactional tools. In contrast, the ASAN MANDI app covers local mandi and provides e-billing, inventory tracking, and ledger management to streamline daily mandi operations. While AMIS excels as an information hub, ASAN MANDI bridges the gap between data and action, enabling users to not only monitor market prices but also manage sales, stocks, and finances digitally.

The performance of ASAN MANDI was evaluated through user feedback survey forms. The survey findings revealed overwhelming acceptance across all evaluated categories, with approval ratings ranging from 82% to 92%. An impressive 88% respondents showed satisfaction over the intuitive interface, and they found it easy to navigate. The bilingual functionality proved particularly successful, receiving a 92% positive response from users, making it more accessible for a wider audience. E-billing feature also scored highly, with 87% users finding it accurate and 82% users acknowledging the improved inventory visibility. While these results confirm the success of the platform's strong usability and adoption, the 12-18% negative responses suggest opportunities for improvement.

Although performance testing was done, scalability is still a potential concern. The internal tests validated the projected transaction volumes the app would manage; however, the real market conditions may be different. During high transaction volumes in a larger mandi or peak business time transactions, the load capacity may be overstretched. To avoid the above potential disruptions, more detailed load testing should be done under varied mandi sizes and seasonal volume shifts. By anticipating the scalability issue in the future, it is easier to guarantee that the app will be able to grow and remain very efficient as more users utilize it. Furthermore, the app needs a proper internet connection, making it difficult to use in remote or rural places, which clearly have little to no internet accessibility.

Moving from traditional Mandi operations that are manual and physical to the digital framework could present a challenge for users who are accustomed to the previous structure. Many of the potential users currently may have low awareness or confidence in the use of newer technology, and this may pose a threat to user adoption and usage of the app. It will be important to address the most critical aspects for the users, such as training sessions, onboarding, and user-friendly instruction guides, to provide an acceptable and seamless transition for users. Furthermore, incorporating feedback from early users will enable the developers to improve the user interface, making it more user-friendly and in harmony with embedded processes.

Conclusion:

ASAN MANDI is a way towards the Digital transformation of Mandi operations in Pakistan by providing solutions to some major problems, such as a lack of transparency, operational complexity, and limited scalability. Due to features like automatic e-billing, efficient ledger maintenance, and inventory management, the app enhances traditional practices by making them easier and conforming to the global shift towards the digitalization of agriculture. The fact that it is available in Urdu as well makes it easier for common people to use.

Thoroughly conducted experiments have shown the app to be capable of enhancing the speed of transactions, reducing the level of manual input errors, and enabling users to have

real-time information about stocks, implying that it can also be used as a digital link that brings together all the players in the Mandi systems. The customization of app features, including offline access and functional enhancements, will be paramount in entrenching the application in Pakistan's agricultural technology landscape and enhancing development while maximizing its transformational benefits.

Author's Contribution:

Ameer Jan: Undertook all aspects of the research and manuscript preparation. This included conceptualizing the study, designing and developing the "ASAN MANDI" app, conducting data analysis, interpreting results, and writing the manuscript.

Zartasha Baloch: Apart from writing the manuscript, she supervised the entire manuscript, providing expert guidance on research methodology, data analysis, and ensuring scientific accuracy.

Madeha Memon: Contributed to manuscript writing, data analysis, and app design.

Aisha Manzoor: Contributed to the design and graphics of the app to make them visually appealing.

Tanzeel Ahmed: Managed the on-field research, designing survey forms, gathering user feedback, and analyzing app performance in real-world settings.

Conflict of interest: The authors declare that there is no conflict of interest.

References:

[1]   S. M. Mustafa Hyder, Noman Ahsan, "Breaking Barriers: Technological Adoption Challenges in Organizations of Developing Economies - A Case of Pakistan," *Voyag. J. Educ. Stud.*, vol. 4, no. 2, 2024, [Online]. Available: https://vjes.voyageams.com/index.php/vjes/article/view/157

[2]   A. S. Raheem Bux Soomro, Sanam Gul Memon, Nisar Ahmed Dahri, Waleed Mugahed Al-Rahmi, Khalid Aldriwish, Anas A. Salameh, Ahmad Samed Al-Adwan, "The Adoption of Digital Technologies by Small and Medium-Sized Enterprises for Sustainability and Value Creation in Pakistan: The Application of a Two-Staged Hybrid SEM-ANN Approach," *Sustainability*, vol. 16, no. 17, p. 7351, 2024, doi: https://doi.org/10.3390/su16177351.

[3]   P. Gobare, S. G., Dandage, M. S., & Jawandhiya, "Development of E-Mandi, an electronic vegetable market platform," *J. Agric. Rural Dev.*, vol. 32, no. 4, pp. 45–60, 2020.

[4]   M. Rehman, S., & Selvaraj, "A review of the state of Indian agricultural marketing: Addressing traditional limitations and the role of digital solutions," *Indian J. Mark. Commer.*, vol. 45, no. 3, pp. 67–79, 2021.

[5]   "Department of Agriculture and Farmers Welfare." Accessed: Jul. 13, 2025. [Online]. Available: https://igod.gov.in/organization/QNe83XQBYNG-XPnvjOsx

[6]   A. A. Reddy and Mehjabeen, "Electronic National Agricultural Markets, Impacts, Problems and Way Forward," *IIM Kozhikode Soc. Manag. Rev.*, vol. 8, no. 2, pp. 143–155, Jul. 2019, doi: 10.1177/2277975218807277;WEBSITE:WEBSITE:SAGE;WGROUP:STRING:PUBLICATION.

[7]   Y. Sekhar, C. S. C., & Bhatt, "Performance and prospects of e-NAM in Haryana: Impact on price discovery and market efficiency," *Haryana Agric. J.*, vol. 15, no. 2, pp. 58–72, 2019.

[8]   S. Swain, P. K., Jamir, C., Dinerstien, M., & Narula, "Contribution of e-NAM to price realization and marketing by farmers in Rajasthan," *J. Rural Dev. Stud.*, vol. 48, no. 5,

pp. 85–100, 2022.

[9] P. V Raju, M. S., Devy, M., & Gopal, "Farmer awareness and engagement with e-NAM: Challenges and recommendations," *Int. J. Agric. Innov. Res.*, vol. 39, no. 3, pp. 92–109, 2022.

[10] S. L. L. Etty Puji Lestari, Sucihatiningsih Dian Wisika Prajanti, Fauzul Adzim, Elvina Primayesa, Muhammad Iqbal Al-Banna Ismail, "Understanding Technopreneurship in Agricultural E-Marketplaces," *Aptisi Trans. Technopreneursh.*, vol. 6, no. 3, pp. 369–389, 2024, [Online]. Available: https://att.aptisi.or.id/index.php/att/article/view/454

[11] P. M. S. Gladys Milena Berns Carvalho do Prado, Elizabete Catapan, Cinthya Mônica da Silva Zanuzzi, Florinda Matos, "Exploring the key success factors: A case study of a digital marketplace platform for Brazilian small farmers," *Procedia Comput. Sci.*, vol. 232, pp. 159–168, 2024, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1877050924000164?via%3Dihub

[12] "AMIS Agriculture Marketing Wing Punjab." Accessed: Jul. 13, 2025. [Online]. Available: http://www.amis.pk/