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Design and Evaluation of Intelligent Commodity Market Information Monitoring System for Rural Farmers and Traders in Ethiopia

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Abstract

Market information in Ethiopia is not readily available to rural farmers and traders. Currently, the existing market system allows intermediaries to decide the market price of the product unfavourably to the farmers. On the other hand, traders cannot not access market-oriented commodities that can be sold at good prices. This paper attempts to design SMS (short message service) based intelligent market information monitoring system that acts as a platform where farmers and traders can share market information in various market domains. The development of the system followed a Rapid Application Development (RAD) approach where testing and evaluation is performed for accuracy, efficiency, usability, acceptance and performance on two crucial aspects of the system: SMS gateway and Query Understanding Engine (QUE). The evaluation and test result of the system is promising. It is found to be that 95% (Accuracy), 89.2% (efficiency), 90.21 (SUS score) and 3.9 seconds (Mean Average performance/speed) is registered. Moreover, User Acceptance Testing (UAT) evaluation showed that it is 'Accepted' for use. It showed that such kinds of systems can solve the problems of lack of easily accessible market information by rural farmers and traders this shows that the system can contribute significantly to improving the accessibility of market information for rural farmers and traders in Ethiopia.

Keywords: *Commodity Market, Market Information, User Acceptance Testing (UAT), Rural Farmers*

Introduction

In Ethiopia, most of the citizens depend on agriculture and its products. Small-scale farmers in rural Ethiopia (GebreSelassie and Bekele, 2012) practise agriculture, which dominates the country's economy. The rural farmers produce market oriented commodities in addition to the foods used for their own consumption. The existing market information system is not favorable and it has left behind both rural farmers and traders. It allows the intermediaries (broker) to decide the prices for the commodities to the farmer unfavourably. On the other hand, the system does not allow the trader to access quality and market oriented products from the producer that can be sold at good prices. In between, the intermediaries are benefitting more than the actual producer, without adding any value to the product.

Accessing agricultural commodity market information is challenging for these participants, especially for the rural farmer, who produces with a lot of effort and cost. Providing easily accessible market information related to the commodities they produce is basic due to the fact that a farmer who benefited from his produce (after satisfying his food need) would have improved the economic, social life and livelihood of his families and himself.

A current scenario that provides commodity market information is by means of using telephone calls, using the mass media, reading magazines and searching websites (ECX, 2010). An existing attempt of using their mobile phones to reach each marketing center is costly and tiresome. Market information notification via mass media is not amenable to both of the marketing participants, in that the information does not address all market areas for each marketing product, and also it is hard to notice information on prices, levels of demand and supply in the markets for such products. The information transmitted on television, for example, does not give enough information to the seller and buyer so that they can bargain to gauge on the prices, quality and quantity of the products they offered to one another. An attempt to use web-based applications is impossible because of limited or high cost of Internet access, poor infrastructure and an illiterate population. Such challenges leave mobile SMS (short message service) applications as a better option for use by rural farmers and traders in accessing commodity market information. SMS/short text messaging (on a GSM network) is a readily available medium that can provide viable solutions for market information like prices of commodities, demand and supply.

There are three major reasons to use SMS as a better communication channel these days especially for rural farmers and traders. Firstly, a SMS application does not require users to adhere to a strict syntax. Secondly, it does not demand high literacy levels on the individual user; it requires only basic literacy skills i.e. it requires reading and writing with few words and numbers. Lastly, the required information can be accessed in their own language from mobile phones available in their hands.

SMS based systems have been applied for a variety of purposes. Health workers in some African countries used SMS based systems to provide diagnosis and treatment services and send educational messages to users via text messages. The Food and Agriculture Organisation (FAO) is using SMS based applications via mobile phone to communicate agricultural reports with field workers (Jaiswal, 2011). The farmers' union in Zambia and rural farmers in Kenya are using text messages via SMS to share market related information with buyers in their own language (Chemweno and Oboko, 2012). Even though SMS based systems are at the infant stage in Ethiopia, many companies are using text messages for sending notification and awareness information to end users. Full SMS based applications are rarely available in Ethiopia to provide information for their services. There are only two SMS based applications, which are made available and accessed through mobile phones to provide information to their target customers (Alemu, 2019). The Agricultural Transformation Agency (ATA) is using Interactive Voice Response (IVR) System to deliver agricultural knowledge and advice and cultivation tips to rural farmers via their mobile phones, whereas the Commercial Bank of Ethiopia (CBE) is using SMS based banking system to enable customers to access their account, make fund transfers and payments and check their balances from their mobile.

Use of mobile SMS to monitor agricultural commodity market information is a viable method to address the current information gap to make the farmers reap the benefit from their produce and improve their lives. In poor African countries like Ethiopia, where there are no media to provide up-to-date marketing information, mobile based SMS applications are highly required. The exploitation of mobile phones and its economic efficiency that can bring to a change in the Ethiopian market system is a good opportunity in these days (Ethio-Telecom Report, 2017, Mittal and Mehar, 2012). Therefore, in this research project, the choice of SMS based systems is highly advisable as it overcomes the easily accessible market information problems of the rural farmers and traders. The research is focused on the possibility of designing an easily accessible SMS based agricultural commodity market information platform where rural farmers and traders can have a direct information access for each other to share, monitor and manage market information in various market domains in which they are interested.

The main objective of this study is to design and develop SMS based automatic and intelligent commodity market information monitoring system platform; test and evaluate the prototype system for accuracy, efficiency, usability, acceptability and performance.

Therefore, the study aimed to answer the following research questions:

1. Can mobile phone SMS be used to solve the lack of easily accessible market information

problems of rural farmers and traders?

2. How one could design and develop mobile phone SMS based market information monitoring system engine, that is effective and efficient, usable and acceptable by the target users?

Research Design

The research population included farmers, traders, system and marketing experts. The researchers purposely selected 20 participants amongst whom were five market experts, five farmers, five traders and five system experts. They were used in consulting, interviewing, data collecting, testing and evaluating the system. The participants were selected based on meeting the objective of the study and accessibility to the researchers.

The data used in this study was gathered from system outputs, test cases, and evaluation checklists. System Usability Scale (SUS) questionnaire (Brooke, 1996), UAT test case template by the San Francisco State University (SFSU) (Thomas, 2000) and database recording for queries sent in and responses sent out by the system were used as convenient data collection methods. SUS questionnaire and UAT test cases were used for calculating usability and user acceptance respectively. Database records were used for determining accuracy, efficiency and performance of the system.

The developed prototype system was tested and evaluated for accuracy, efficiency, usability and acceptance. The overall evaluation was mainly performed on the two crucial functional aspects of the system, QUE and SMS gateway. Determining the accuracy of the system was conducted by comparing responses of the system to expected responses, i.e. how many of the queries sent by users are correctly understood by the Query Understanding Engine (QUE) and correct responses are sent to the user.

This can be computed by assigning a binary value of '1' if the user finds correct responses by the system for his queries and '0' if he/she does not

$$\text{Accuracy} = \frac{\text{The number of correct responses determined by the system}}{\text{The number of expected responses stored in the database}} \quad (1)$$

Efficiency of the system was evaluated by measuring how much time taken by the system to correctly understand user queries and send correct responses to the user. The overall relative efficiency was used in the study as it measures the success of the system relative to all users. The equation can thus be represented as follows (Justin, 2015):

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$$\text{Overall Relative Efficiency} = \frac{\sum_{J=1}^{R}\sum_{I=1}^{N} n_{ij}\, t_{ij}}{\sum_{J=1}^{R}\sum_{I=1}^{N} t_{ij}} \times 100\% \quad (2)$$

Where:

N = the total number of tasks (queries)

R = the number of users

nij = The result of task i by user j; if the user successfully completes the task, then nij = 1, if not, then nij=0

tij = The time spent by user j to complete task i. If the task is not successfully completed, then time is measured until the moment the user quits the task.

This serves to measure and evaluate users' impression of the overall ease of use of the system being tested. Usability (test for satisfaction) involves task level1 and test level satisfaction approaches. The test level satisfaction was used as it measures the system's usability from the perspective of all users (testers) at the end of the test session than individual user tasks unlike task level satisfaction approach. SUS is a test level satisfaction method that is used for testing and evaluation of usability in this study to measures the perception of usability of the system by the users (Sauro, 2011). SUS is a 10-question item, and its value for the whole respondents is calculated as follows.

$$\frac{\sum_{n=1}^{n} 2.5 \sum((\times^{+ve} - 1) + (5 - \times^{-ve}))}{n} \quad (3)$$

To determine whether or not the software system has met the requirement specifications and criteria, UAT test cases are prepared based on UAT test case template by the San Francisco State University (SFSU) and given to users for testing. Test cases were developed based on test scenario, test steps, parameters, expected result, and actual result fields. alpha testing1 (Leung and Wong, 1997) was used to test for the acceptance of the ten alpha testers who were comprised of the working organization. They have been given trainings to use the system and set them to test cases against the test scenario. Based on the results of testers, the research team then had to decide whether to accept or reject the system. In addition, the system was developed following the Rapid Application Development (RAD) methodology with testing and evaluation was performed iteratively.

RAD entertains more user participation, little or no user resistance with fast development feature which were the reasons for selection. Java Scripts with GlassFish server were the familiar programming tools for the development. Generally, the development process continued until highest evaluation metrics were achieved and end users' level of satisfaction was believed to be maximised. The overall evaluation based on final version was presented as a final result in this study. Meanwhile, the conceptual design (architecture) of the system was redesigned at every stage of the system level and a final version was drawn. Moreover, the researchers tried to interpret the results found in the experimentation and forward their conclusions.

System Design

This section discusses the design of functional modules of the system; the system's architecture and design assumptions and constraints.

The system consisted of the design and integration of SMS gateway, Query Understanding Engine (QUE), database and web interface. The architectural design of the system shown in Figures 1 and 2 included the design and development of these key modules into the system.

SMS gateway: SMS Gateway acts as an interface between the computer system and the mobile phone and is responsible for receiving user queries and messages and sends back the requested message from the system to the end user. Since the services of SMS gateway are delivered by the existing telecom service provider, SMS gateway design considers only technical configuration to connect to our system.

Query Understanding Engine (QUE): The QUE is responsible for fetching query messages from the database, analysing (process) the transactions (the message) and storing the processed data back to the database. And then the processed message (as a response) is fetched and delivered by SMS gateway to the user via SMS. The QUE handles incoming queries in natural language (Amharic) and responds after performing intelligent internal operations. This internal operation involves accepting queries (keywords) sent from user, converting these queries into formal SQL queries; these are then applied against the database. The user sends messages to the QUE based on a pre-specified syntax (easy to be converted to keywords) that show the sender's interest in either the price of a product in a given market or their interest to a product for sale or buying at specified market location. In this study, methods from paper (Chemweno and Okobo, 2012) was adapted and improved the design of the QUE to receive all incoming messages based on the format "[INTENTION] [PRODUCT] [MARKET]" which is suitable for the processing by the QUE and to the underlined language Amharic. The INTENTION specifies the intention of the sender, i.e. price inquiry, placing offer to sell or offer to buy. PRODUCT stands for the agricultural commodity that the sender is inquiring about or intending to buy or sell. MARKET refers to the market place that the sender is interested in. Sometimes, the QUE may not understand all incoming users' queries. These are un-understood messages which can be easily monitored from the dashboard by the system administrator who apply human touch to provide their understanding of user's intention and it will become active for processing. This will help to reduce the messages that go unanswered. The overall process is shown in figures 1, 2 & 3.

Database: A database stores incoming messages (user queries), prices, sent messages, unprocessed data, and other system transactions.

Web interface: Web interfaces acts as dashboard where a system administrator monitors everything over there. The web-interface is used to view un-understood messages, incoming and outgoing messages, transactions and reports.

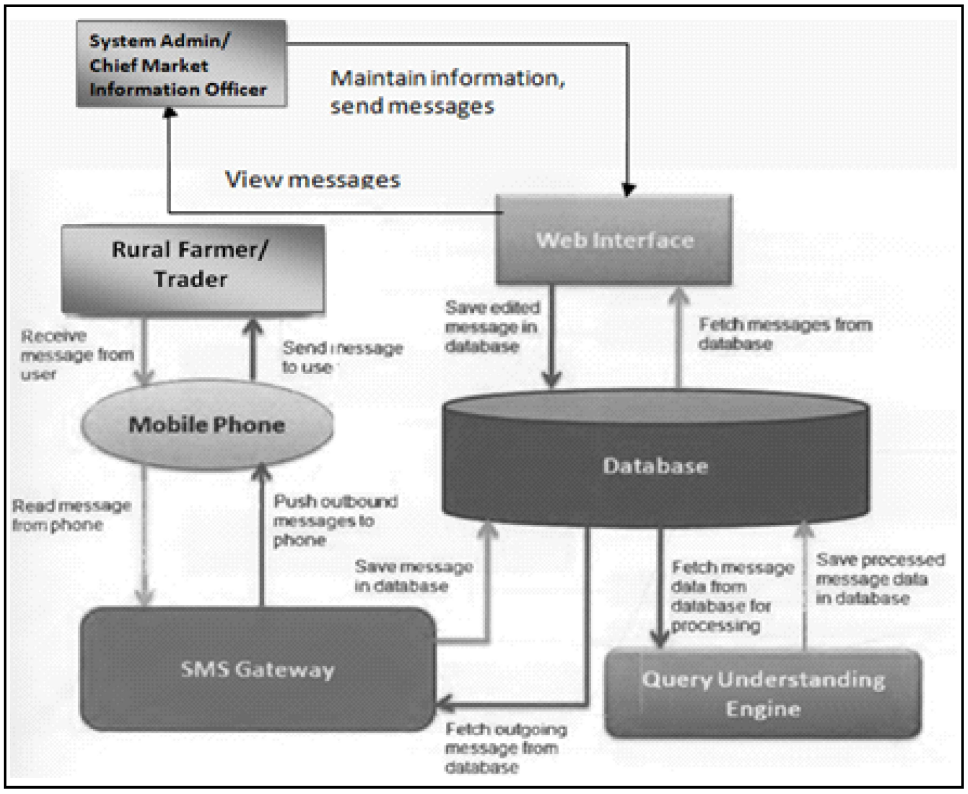

Fig. 1: Integrated components of the prototype (model) of the system

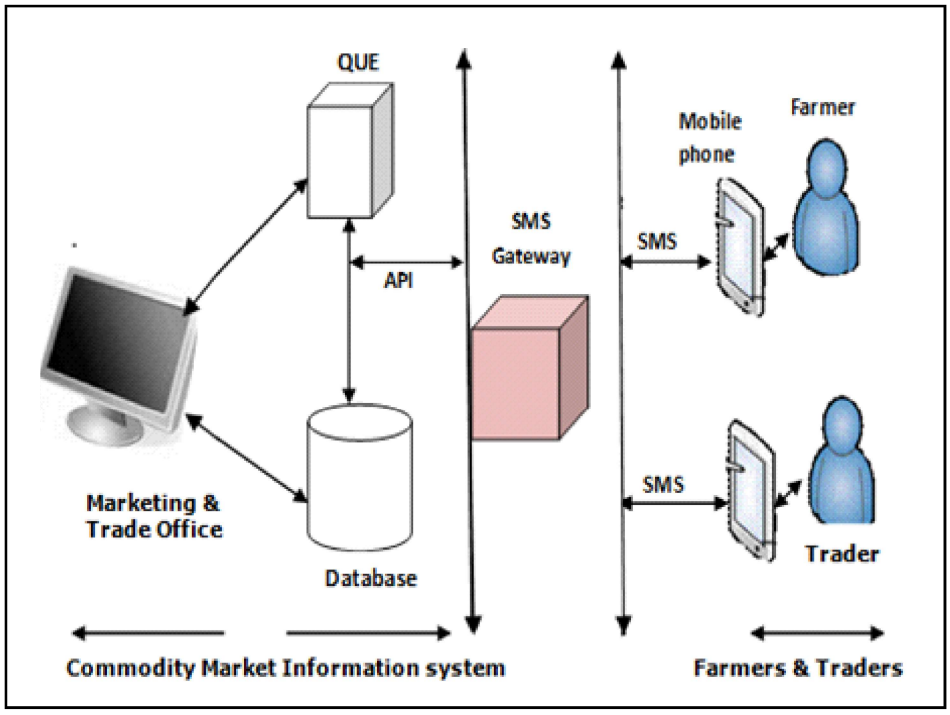

Fig. 2: Architectural Design of the System

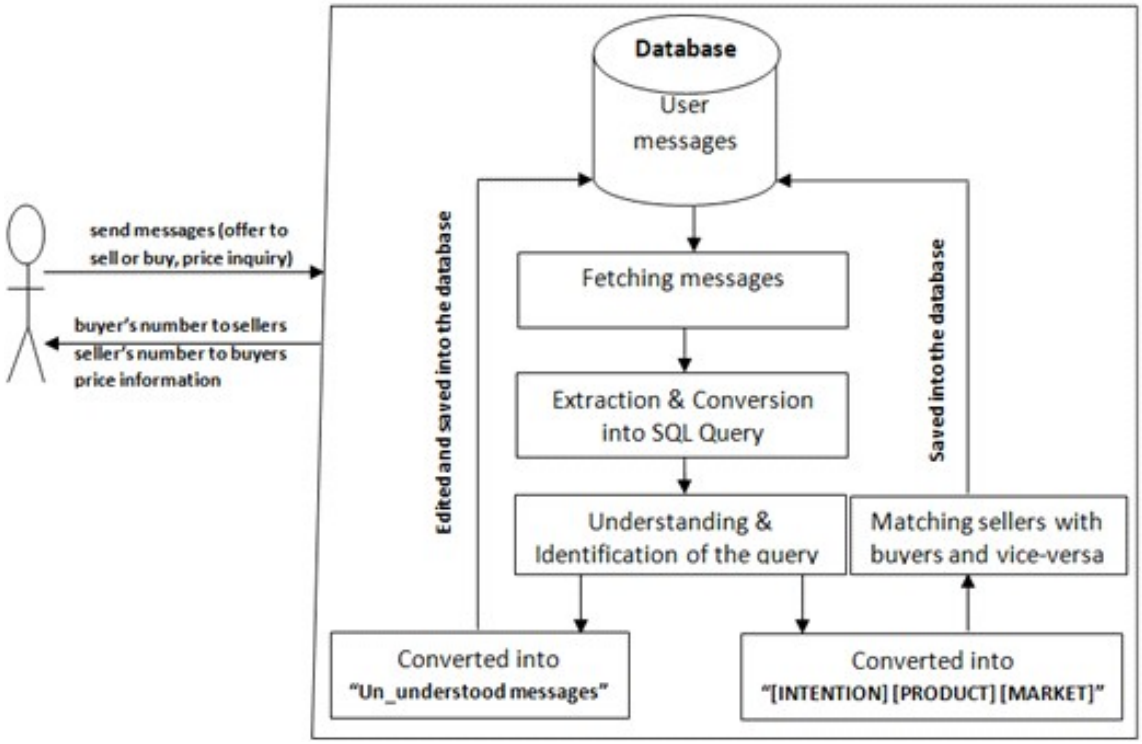

Fig. 3: Intelligent operations of the system

Conceptual Framework and Basic Assumptions: In Ethiopia, rural farmers live and work in areas where access to education is limited. Designing systems of this kind for use by users in these areas will have a usability problem. In order to address such challenges, the study proposed and formulated a conceptual framework that guides the design and development of the system. Pictorial representation of the framework is shown in Figure 4.

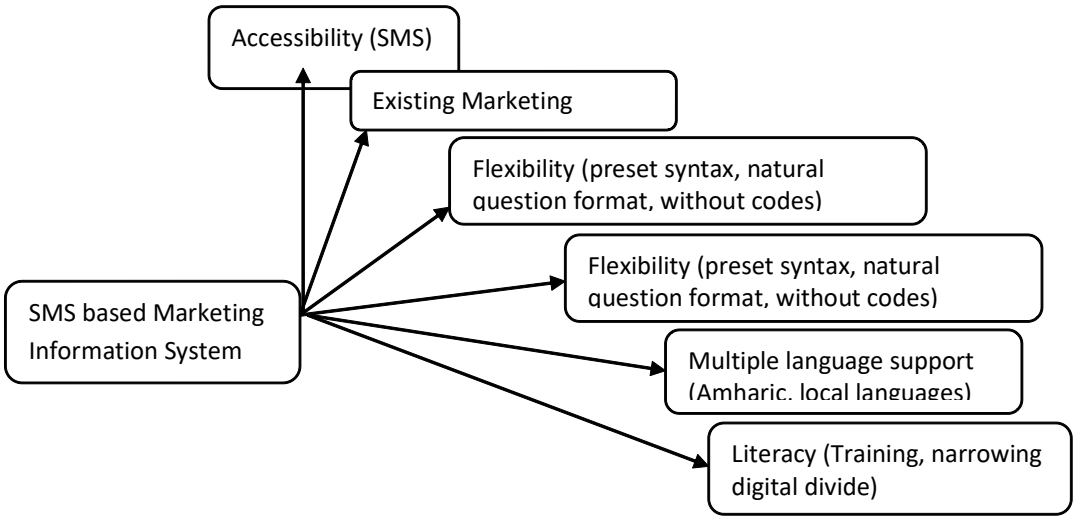

Fig. 4: Conceptual framework of the system. Adapted from (Alemu, 2010)).

Accessibility entails the availability of ubiquitous media that the system is looking for to easily support the market information needs of the user. Hence, SMS, as easily available channel, is taken due to the fact that it does not require sophisticated technology skill to provide an information access to the farmers. Providing services of the system through their own local language is believed to be significant for the usability of the system. The framework should prioritise the use of a predefined-syntax where users can communicate in a more flexible manner. The framework addressed the usability design of the system based on the assumption that the system requires low-level literacy skills such as reading and writing in their own languages from their mobile phones.

Results and Discussions

This section highlights the results of testing and evaluation of the system, particularly the two crucial parts of the solution: SMS gateway and query understanding engine (QUE). Testing and evaluation of the system includes functional evaluation, accuracy, usability, acceptability and performance. Respondents who participated in testing and evaluations were few in number. However they participated across all previous versions of the prototype system including the final version. The testing and evaluation results based on the final versions are presented below.

Functional Evaluation

This section presents the evaluation of the functional activities related to SMS gateway and QUE for performing their intended tasks successfully or not. The evaluation was conducted as follows.

Send offers to sell or buy: From the total collection of twenty offer messages sent by users in which ten offers were "being buy" and the remaining were "being sell", it was inspected that all the twenty well-formed offers were received and processed correctly. In addition to this, the system identified and correctly processed contacts of sellers to the matching offers by buyers and contacts of buyers to the matching offers by sellers.

Inquire product prices: Evaluating price inquiry involved sending messages that have an intention of inquiring for prices of different commodities with a format "Price Maize Bure"/ in Amharic, "Ë– `F a,". The prices were the first recorded form in the database and with prior knowledge of the prices, messages were sent to query the system for these known prices. The results were impressive with all the ten inquiries yielding correct results.

Edit un-understood messages: Messages that were not classified to one of {offer to sell, offer to buy, price inquiry} were classified as un_understood and saved in un_understood messages. Editing involved a human touch by the system administrator and updating the record with a resolution message. A set of ten messages were edited and saved back to the database. All the messages edited were properly saved in the form they were edited to the proper database table.

In general, design and development of the system mainly focused on creating the platform that provided a bridge services ("not just a broker") whereby a rural farmer is be able to place offers for their products and intend to sell and on their part, traders were able to advertise commodities they wished to buy from farmers. These offers to sell and buy were matched by the system with buyers receiving contacts of sellers and sellers receiving contacts of buyers. At this point, the two parties could communicate using their phones and strike a deal. The system also helped users to make price inquiries on a specific product. Meanwhile, if there are messages that are not understood by the QUE, it forwards to un_understood message for a further human touch. Figure 5 shows the pseudocode for the overall operation of QUE.

Usability Evaluation

Accuracy*:* The accuracy (effectiveness) of the system is measured by evaluation how the Query Understanding Engine (QUE) correctly understands many of the queries sent by users and correct responses are sent to the user. The result showed that from twenty well-formed queries sent to the system,

```
Begin
   User:    Send offers to buy
            Send offers to sell
            Send price inquiries
   System: Match offers to buy with offers to sell
            Send buyers no to sellers or sellers no to buyers
            Send price of a product to requesters
            Send un understood message for further editing
End
```

Fig. 5: Pseudocode for QUE

the system correctly understood, processed and sent correct responses to only nineteen of them. The error is marked due to un_understood messages. It was also inspected that for correctly edited and processed offer or price inquiry messages, the system result showed 100% correct.

$$\text{Accuracy} = \frac{19}{20} X100\% = 95\%$$

***Efficiency**:* Out of twenty users who used the system to send offers to sell or buy and inquire prices of a commodity, the system resulted as shown in Table 1. The table shows the user performed two different tasks (Task 1 and Task 2) at different times and the time taken by the user to successfully perform his/her task using the system. These raw data were collected from the system database via a web interface. Using equation 2, the overall relative efficiency is calculated for both tasks separately as follows.

Table 1: Time statistics for Task 1 and 2

User	Task 1: send offers to sell or buy (n_{ib})	Time taken(t_{ij})	$n_{ij}t_{ij}$	Task 2: inquiring prices (n_{ij})	Time taken (t_{ij})	$n_{ij}t_{ij}$
1	1	4	4	1	3	3
2	0	5	0	1	2	2
3	1	4	4	1	5	5
4	1	5	5	1	2	2
5	1	4	4	0	2	0
6	0	3	0	1	3	3
7	1	4	4	1	5	5
8	0	3	0	1	3	3
9	1	5	5	1	3	3
10	1	4	4	1	3	3
11	1	5	5	1	5	5
12	1	5	5	0	2	0
13	1	6	6	1	4	4
14	1	5	5	1	3	3
15	1	6	6	1	3	3
16	0	3	0	1	4	4
17	1	7	7	1	4	4
18	1	4	4	1	4	4
19	1	3	3	1	3	3
20	1	5	5	1	4	4

As shown in table 1, most users were successfully completing their tasks (marked as 1) i.e. the system received their offers, processed successfully, and saved into the database. However others were not successful (marked as 0) because of two reasons: one, there exists an un-understood messages in the database such that the QUE quits transaction; secondly, being an SMS application, this system's performance depends to some extent on the speed of the mobile operator in delivering SMS messages. The overall relative efficiency is calculated for both tasks separately as follows using equation 2.

Overall relative efficiency (using Task1)

$$= \frac{(1*4)+(0*5)+(1*4)+\cdots+(1*4)+(1*3)+(1*5)}{90} X100\% = 84.44\%$$

Overall relative efficiency (using Task2)

$$= \frac{(1*3)+(1*2)+(1*5)+\cdots+(1*4)+(1*3)+(1*4)}{63} X100\% = 94.03\%$$

As we have seen here, users were more efficient in performing task 2 than task one. This is because the price information saved in the database was prior knowledge and was updated by the expert or system administrator. So that there will be less possibility of error of processing than users performing Task 1. The mean average overall efficiency of the system is found to be 89.23%.

Usability (satisfaction): Usability measures all aspects of a system that determine user satisfaction, user perception and overall ease of use. For this test, results were collected through questionnaire and analysed using the standard SUS formula as shown in equation (3). Out of 20 respondents who were involved in usability testing, the average SUS was found to be 90.21%. This result showed the system is easy to use and is more likely recommended for use.

UAT Evaluation

After successfully completing the UAT test cases, every tester provided their test results. An actual result, which a tester gets after performing the test, was documented along with the test case during the test execution phase. After performing the tests, the actual result was compared with the expected result and the deviations (if any, is known as defect) were noted. The defect goes through the defect life cycle and the testers address the same after fix. While in each test, after getting the actual result, the test scenario was given a "PASS" or "Fail" mark.

Table 2 presents the final version UAT test results by ten testers. If the test had marked with at least one 'fail' in one of the test case, the developer has gone back to fix bugs, errors and defects that cause 'fail' mark. In such a case, the test had passed three UAT test iterations before the final UAT test version with no 'fail' mark and critical comment is produced. The overall UAT test result showed that the system is accepted for delivery/use.

Performance Evaluation

Being an SMS application, this system's performance depends to some extent on the speed of the mobile operator in delivering SMS messages and the existing Telecom infrastructure. As the performance tested by ten users as shown in Table 1, the average time it registered for sending offers to sell or buy and inquiring prices were 4.5 and 3.35 seconds respectively. While the system is being practical, it is believed that the performance might be better with messages sent during off working hours and the night. With further optimisation, the system could perform even better. As per the knowledge of the researchers, there were no systems of which the evaluation was made to compare them to a system with which the one developed in this research project.

Table 2: Final UAT Test Results

S/N	Test Scenario/case	Test Step	Expected Result	Actual result	Pass/Fail
1	Test and check users can send offers to sell or buy	Open the SMS application and send offers to the system	The system should be able receive inputs and process successfully	The system receives inputs and process successfully	PASS
2	Test and check the system store / receive incoming messages (offer to sell or buy, price inquiries)	Log into the system and send messages	The system should be able to store/ receive messages sent from users	The system stored/ received messages sent from users	PASS
3	Test and check that the QUE understand incoming messages and label those that don't understood it	Log into the system and send test messages	The system should be able to understand messages	The system understood test messages and label them successfully	PASS
4	Test and check the system respond to user queries	Open the SMS application and send offers and inquiring prices	The system should be able to respond to user queries	The system responded successfully to user queries	PASS
5	Check that the system help the admin to edit un-understood messages	Log into the system and edit un_understood messages	The system should be able to help the admin such un_ understood messages	The Admin edited un_understood messages and properly saved in the form they were edited	PASS

Conclusion and Recommendation

As more mobile phones become available in the hands of rural farmers, SMS based systems are the better tool for their information access. SMS based agricultural commodity market information monitoring systems are designed and developed to solve the problems of lack of easily and readily accessible commodity market information by rural farmers and traders in Ethiopia. SMS based systems can give appropriate solutions to provide market information timely. This kind of system does not require sophisticated skill; low-level literacy users including rural farmers can easily utilise them. The result of testing and evaluation of the system has met the objective of the study. The system can play a significant role in improving the livelihood of rural farmers and traders in Ethiopia. The researchers highly recommend that future researchers should improve the system in the areas of additional transactions such as analysing and predicting trade volumes, market flows, market predictions and growing conditions.

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