

Design Science Research Based Blended Approach for Usability Driven Requirements Gathering and Application Development

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Abstract—Extracting user requirements in designing innovative ICT based solutions for emerging vague problems is a challenge. We successfully addressed this challenge by blending several techniques in Software Engineering (SE) and Human Computer Interaction (HCI) within a Design Science Research (DSR) framework. These techniques were traditional surveys and interviews, causal analysis, scenario creation and transformation, use of paper-based and functional prototypes for communicating with users and capturing their feedback, user centered design, and incremental development. This approach enabled us to better capture requirements based on usability aspects and guided us to design a successful solution. We present a framework derived from this research for wider applicability.

Index Terms—Design science research, usability, information and communication technologies, human computer interaction

I. INTRODUCTION

Advances in Information and Communication Technologies (ICT) have enabled us to develop innovative software applications including for mobile devices to meet a range of requirements. At one end of the spectrum there is a demand for modifications or enhancements of current functional aspects of pre-existing ICT systems due to evolving user requirements. In the middle of the spectrum there is a demand for developing new ICT systems for well understood business processes often partially automated by different software applications but not fully integrated to meet user needs. On the other end of the spectrum there is a huge potential for providing new ICT based solutions for problems people are facing in performing their daily work tasks due to lack of information or computing tools where the business processes are fairly ad-hoc.

Irrespective of the problem being addressed, gathering correct user requirements is a challenge. When compared with the first two broad types of application areas, gathering requirements for the later type of applications is a major challenge. In the first instance, stakeholders have a fairly good

idea about the new requirements as they are aware of the shortcomings in the existing system. Thus, requirements can be easily gathered by using standard methods such as direct interviews and surveys. In the second instance, as the new ICT based solution is designed for a well defined business process, the stakeholders are often in a position to express their requirements either partially or completely. However in the third instance, stakeholders are unaware of the nature of the potential ICT based solution. The ad-hoc nature of the business processes makes gathering the requirements even more difficult. The problems of this nature require new ways to derive requirements.

The developed system should not only meet the functional requirements but also be easy to use by the intended users[1]. Thus the system should be designed with usability in mind. This requires identifying usability requirements which is another major challenge. However, due to the competition among various developers and complexity in designing interactive solutions, less importance is given to meeting usability requirements. The negligence in this regard has created a huge impact in achieving the intended objectives as users are reluctant in using such complex designed solutions [1]. We have developed an innovative solution to a problem of the third type successfully incorporating both functional and usability requirements. By generalising our approach in this paper we present a framework in which different techniques are blended together to gather requirements incorporating usability aspects.

This work was performed by an International Collaborative research team which consists of researchers from Sri Lanka, Australia, Italy and USA.

The rest of the paper is organised as follows. Section II provides a literature review on the existing methods available for capturing usability requirements. A concise description of the problem domain is presented in section III. The section IV describes the characteristics of usability and the way we

achieved each characteristic while empowering the intended users. Section V illustrates the generalized framework we derived from this research. The last section presents the conclusion and future directions.

II. LITERATURE REVIEW

Experts agree that software “quality in use” is strongly influenced by the level of usability achieved. A systematic process to elicit, specify and test usability requirements is considered paramount to guarantee that the software product will be eventually deployed for its intended users [2].

In a seminal work, Good et al. [3] describe usability engineering as a process grounded in classical engineering, which aims at developing a software product taking into account a set of early specified measurable characteristics that the product is expected to have. The process succeeds if the product is demonstrated to have the intended characteristics. The authors also highlight that the specification of measurable usability characteristics is crucial to determine the usability requirements of a product, or to measure whether or not the finished product fulfils such requirements.

Although practitioners are aware of the importance of including usability requirements, it is often the case that the elicitation, specification and evaluation of such requirements happen late in the development process [1].

Several techniques have been proposed in the literature to formally specify usability requirements addressing user’s goals and to test the developed prototypes against established usability measures [4, 5]. Most of them were derived from practical experience in industrial settings. However, only few methodological approaches to usability engineering have been proposed so far, that integrate existing techniques to support a holistic view of computer systems as part of a social organization. Most of such approaches are not general but rather address the applicability of traditional usability engineering techniques to specific domains, such as web application and mobile application domains. In particular, a methodology to understand the users’ needs and identify usability requirements of web applications early in the development process is proposed in [6]. The authors highlight the importance of an integrated set of technologies supporting the focus on usability requirements throughout the development of a web application.

In the domain of mobile applications, indeed, the characteristics of mobile devices (e.g., small size of display, power limitation, connectivity features) as well as the ever-changing user’s context, makes usability requirements elicitation a further complex activity [7, 8]. Usability requirements derived from factors like the level of literacy of the intended users, their familiarity with mobile technology, their cultural background, and their religious beliefs may lead to the discovery of additional functional requirements [2]. In previous work we underlined the tight interrelation between usability and functional requirements, showing that a deep knowledge about potential users and about their needs can be progressively acquired during an iterative process, where users’ participation is highly recommended [9].

III. PROBLEM DOMAIN

It is a regular occurrence in Sri Lanka that farmers are faced with over-production [10-14] of some vegetables and under supply [15] of others. This has a major impact on their expected income [16], which in turn has an impact on the economy as a whole. This is evident from the continuous labor lost within the last two years in the agriculture domain of Sri Lanka [17]. In late 2011 when we discovered this problem there was no long-term solution. Most of the time at such instances the government of Sri Lanka implemented temporary solutions to protect the farmers. The imposed temporary solutions neither could address the issue nor could reduce the damage caused. During our investigations we saw a potential long-term solution using advances in mobile technology based on exponential growth in mobile, internet and email subscribers in Sri Lanka [18].

The populations that we were targeting to provide a mobile-based solution for the over-production problem are not technology experts. We interviewed and surveyed 123 farmers. We observed that the computer usage (20%) among the farming population is relatively low compared to the mobile phone usage (92%). At the same time, during our surveys we also identified the possibility among the farmers to buy a smart phone was higher than buying a computer. Low cost and accessibility are the main reasons for their choice. Based on these findings we decided to develop a mobile-based solution.

From the data gathered from the interviews it became clear that the over-production problem was only a symptom of a much deeper problem [16]. Most of the interviewed farmers were traditional farmers and they were compelled in growing the usual crops that they are well familiar. The knowledge on what crop to grow is gained mainly based on the practical experience as well as from the elders. It was also observed that farmers had no way of knowing what the current production levels for a crop is at the time of deciding a crop to grow except observing what the neighboring farmers are growing.

Different selling mechanisms are adopted by farmers in Sri Lanka. Some bring the harvest directly to the market, while around 90% depend on a middle person, namely the transport agent or the shop keeper. However, none of them get help from the government to sell the harvest. Another interesting fact is the behavior with respect to the selling prices. The selling price is a dynamic value which changes very frequently at a particular market. The farmers reported that they were often unable to predict the price as it changed vigorously within few hours. The major problem was that they were unable to gain a good price for their harvest at the market, because all farmers tend to grow the same crop at the same time.

Below, we summarize the most important claims about the domain specific issues identified from the interviews:

- Users were disposed to use some technological instruments provided that they are not invasive;
- Governmental centres aimed at supporting agricultural activities are located all around the farms;
- There was a very low level of trust among the members of the same community, insomuch as not sharing basic information about their crop production.

IV. EMPOWERING THE USERS THROUGH USABILITY

Usability is a major concern of any interactive software solutions [1]. According to ISO 9241-11 Ergonomics of Human System Interaction -Guidance on Usability (1998), the term usability is defined as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. The approach we took enabled us to increase the product usability by designing the system to meet effectiveness, efficiency and satisfaction.

A. Goal Identification

The first step to achieve good usability is to clearly identify the intended goals that the users are aiming to achieve using the system. Goal identification can be done at multiple levels ranging from broad range of daily activities to specific functionality relating to well defined business process. In situations where the process is well known identifying goals is an easy task. Under these circumstances normally, interviewing the user, observing the existing solutions and the business process, will enable requirements to be identified. We could then structure the approach to achieve the specified goals from the software according to software engineering norms. However, in cases where the existence of an imprecise process and absence of any existing solutions, deriving goals is a much harder task.

In this work, our main motivation was to identify a solution for the over-production problem of crops in the agriculture sector of Sri Lanka. As it was found that the problem observed was only a symptom of a much deeper problem. This motivated us to gather more information to identify the causes behind these issues. This resulted in creating a causal map [16], based on data gathered by interviewing farmers and other stakeholders in the agriculture domain. From the causal map we were able to identify the root-cause which was farmers being unable to access required information at the right time in the right context.

We developed several personas and scenarios for the problem domain [9] to better understand the impact of not having right information at the right time. By, scenario development and transformation methods the research team got a better understanding of the system goals. We were able to arrive at a potential solution where the production quantities along with cultivated crops are shared by the farmers via mobile-based system. In fact the major functional requirement was that the proposed application would allow the exchange of heterogeneous data between neighboring farmers guaranteeing anonymity. By sharing valuable information on crop cultivations, users would be able to make better decisions during the crop selection activities. Furthermore, because of social phobia and the competition among farmers, users were more conformable sharing information while preserving anonymity. Other requirements derived from the surrounding environment. For example, users might be using noisy production equipment or they might be speaking with co-workers while using the application in the field.

These findings led the researchers to design the first mobile interfaces of the proposed solution [9]. This was the first visualization of the information on a mobile interface. The design gave us a clear idea on how to present different information required by the farmers on a mobile platform. In addition to the required information the design also visualized a mechanism to input the production quantities. The production quantities were further supported by a color scheme to give an influential message to the farmers when deciding on a crop. Iterative evaluations using the designed interfaces resulted in developing the first working mobile prototype to share production quantities.

The design and development of the causal map, mobile interfaces and the mobile prototype enabled us to identify the overall system goals of the solution. In addition to information/requirements goals we further identified the importance of user empowerment [19]. This factor will motivate the users to get and provide information from the system. Testing the initial mobile prototype with targeted user groups revealed the importance of designing the user interfaces based on their cognitive, education and cultural background.

B. Design for Effectiveness

Effectiveness of a solution is the “accuracy and the completeness with which users achieve certain goals” [20]. Stakeholders of an ICT based system value accurate and complete information. This is one of the characteristics that would empower the user to use the system. Users will get motivated to share information when they experience the benefit that they would receive in return.

Farmers need accurate and complete information at the time of making decisions in their farming life cycle. Thus, the system should be capable of providing the right information at the right context. Based upon this objective we identified the ways to provide accurate and complete information for the farmer. We evaluate the effectiveness of the solution throughout the process at different stages by measuring the quality of the designed solution. A thorough literature review enabled us to identify information needs of the farmers at different stages of the farming life cycle. Based on an extensive survey conducted by Lokanathan and Kapugama [21] we further mapped these needs to different stages and identified the need of personalised information to increase accessibility. As such we designed user registration system that captures some aspects of their context such as farm location to provide personalized information to the farmers. For example a farmer can use the system to query what crops will grow in his farm. To respond to this query geo-coordinates based on the farm location captured at the time of registering will be used to identify the corresponding agro-ecological zone. Based on the agro-ecological zone we can obtain the related environmental factors such as temperature, rain fall, soil type etc relating to the farm. Using this information we query a crop ontological knowledge base to find a list of crops that will grow in that particular farm.

To arrive at the above design we started with the crop selection stage of the farming life cycle to identify detailed information needs of the farmers. This is the stage where

farmers make critical decisions in identifying what crop to grow in which quantity. The decision made at this stage will influence the revenue at the selling stage. Thus, providing accurate and complete information at this stage is a crucial need. Therefore we conducted several field visits and surveys to gather detailed requirements. Grounded on these findings we further designed the mobile interfaces for the crop selection stage. These were iteratively tested with farmers to ensure the information provided is what is required by them. During such evaluations farmers stressed the importance of getting accurate and complete information.

Feedback received during these surveys enabled us in designing the backend databases, crop knowledge repository and Web Services for the front end mobile applications to retrieve and store information. Applying the theory of empowerment, we further designed and developed an application to calculate profit based on “what-if” scenarios [19]. The first working mobile artefact emerged as a result of these combined activities. This was developed for a mobile running on Android 4.0 targeting the crop selection stage. This mobile artefact was tested with a sample of 32 farmers in Sri Lanka. Working mobile prototype, questionnaire and interviews were used as main research instruments in this evaluation. Questionnaire comprised of multiple choice, Likert scale and open-ended questions. One of the several objectives of this field trial was to evaluate the effectiveness of the solution. We gathered statistics in relation to the completeness of the information provided. This is to ensure and to further identify detailed requirements needed by the users. In addition to that we also gathered data on the effectiveness of the features provided in the system in decision making. Table 1 provides a summary of the findings. Further details on this evaluation can be found in [22].

TABLE 1. Percentage responses received from a sample of 32 farmers on the information provided and the effectiveness of the features provided in decision making (SA-Strongly Agree, A-Agree, MA-Moderately Agree, DA-Disagree and SDA- Strongly Disagree

<i>Question</i>	<i>SA</i>	<i>A</i>	<i>MA</i>	<i>DA</i>	<i>SDA</i>
All information for the crop choosing stage is provided	7%	57%	37%	0%	0%
Information is sufficient for decision making	3%	43%	50%	3%	0%
Knowledge on history is important	53%	47%	0%	0%	0%
Market prices are important in deciding a crop	47%	33%	20%	0%	0%
Crop comparison facility is essential in deciding a crop	62%	34%	3%	0%	0%
Color code usage is important in deciding a crop	57%	37%	3%	3%	0%

C. Design for Efficiency

With the targeted population efficiency is another major characteristic for the success of the solution. Since the targeted population is new to this type of a solution achieving efficiency

will empower the user to use the system. The efficiency of a solution is measured using “the resources such as time, money or mental effort that have to be expended to achieve the intended goals” [23]. Task completion time or effort will rely on the efficiency of the interfaces. User interfaces (UI) should be designed for user to complete the required task with minimum effort. Otherwise the users will get less motivated. Thus, a user friendly interface with an easy navigation scheme is necessary to increase the speed in getting and sharing information.

Having identified this need we have designed user friendly interfaces while iteratively testing the interfaces with farmers. We employed the paper prototype technique in HCI to get a quick feedback on the design. Further, we have applied several methods such as knowledge injection and UI design based on HCI techniques to enhance the look and feel of the interfaces. This iterative process enabled us to design a better set of UI’s to provide the requirements of the user. Our main intension of this iterative process is to produce a set of UI’s that will minimize the effort of using the system. Thus, we evaluated our first working mobile prototype to explore the extent to which we achieved efficiency. We used indicators such as time to complete a task and the required effort to achieve the intended goals in this evaluation.

This evaluation was carried out using a sample of 32 farmers. We gave them three tasks to attend after a training session. More information on these tasks and the evaluation findings can be found on [22]. In Table 2 we have summarized the analysis of the task completion time.

TABLE 2. Task completion time in minutes based on sample of farmers

	<i>Task 1</i>	<i>Task 2</i>	<i>Task 3</i>
Median	4	2	1
Mean	4.909091	3.142857	1.777778
SD	3.61095	2.6886	2.602161
Mode	2	1	1

As shown in Table 2, farmers were able to complete the tasks on average less than 5 minutes. Further, we would also like to mention that except for 2 smart phone uses reset of the farmers in this sample has never used a Smartphone before. Their first use of a Smartphone was at the training session.

D. Design for User Satisfaction

In addition to achieving effectiveness and efficiency, the user should also be satisfied with the system. Thus user satisfaction in this regard has a huge impact on the success of the solution. Thus, it is essential to measure user satisfaction to identify their comfort and attitudes towards the system [20]. User attitudes can be measured using standardized methods such as SUMI [24]. Efficiency, affect, helpfulness, control and learnability are the five subscales used in SUMI to measure satisfaction. For the initial evaluations we used affect, helpfulness and learnability to measure their attitudes towards the system.

Mobile prototype including paper and the mobile versions enabled us iteratively to evaluate the solution for user satisfaction. During such evaluations affect or the likeliness to use the system was recorded to be 100%. Their attitude towards learnability is positive. However, some of the users stressed the need of a training session to better identify the features to reap the benefits. We also observed that these user groups need more guidance to use the application by providing various help facilities.

V. RESEARCH APPROACH AND DISCUSSION

The characteristic of usability effectiveness, efficiency and satisfaction were achieved through usability requirements which evolved from the beginning of the research as mentioned above. This was facilitated by the adapted methodology; Design Science Research (DSR) [25]. Further, DSR enabled us in deriving detailed requirement needs of the user.

DSR is a matured research methodology in Information Systems (IS) [25-27]. This is a “problem-solving paradigm” [26] which seeks for an innovative solution to increase the efficacy through development of an artifact. In literature we can find various DSR process models aligns with various disciplines [25-28]. DSR has been successfully applied and validated in the IS research community. Peffers et al. have proposed a process model for presenting and appreciating DS research in IS [25]. As shown in Fig. 1, this process model includes six major steps namely: Problem identification &

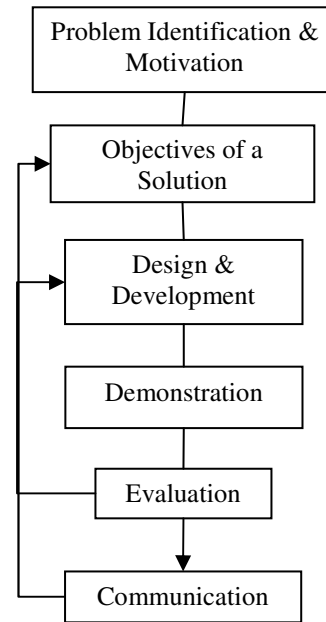


Fig. 1 Design Science Research Process

motivation, Objectives of a solution, Design and development, Demonstration, Evaluation and Communication.

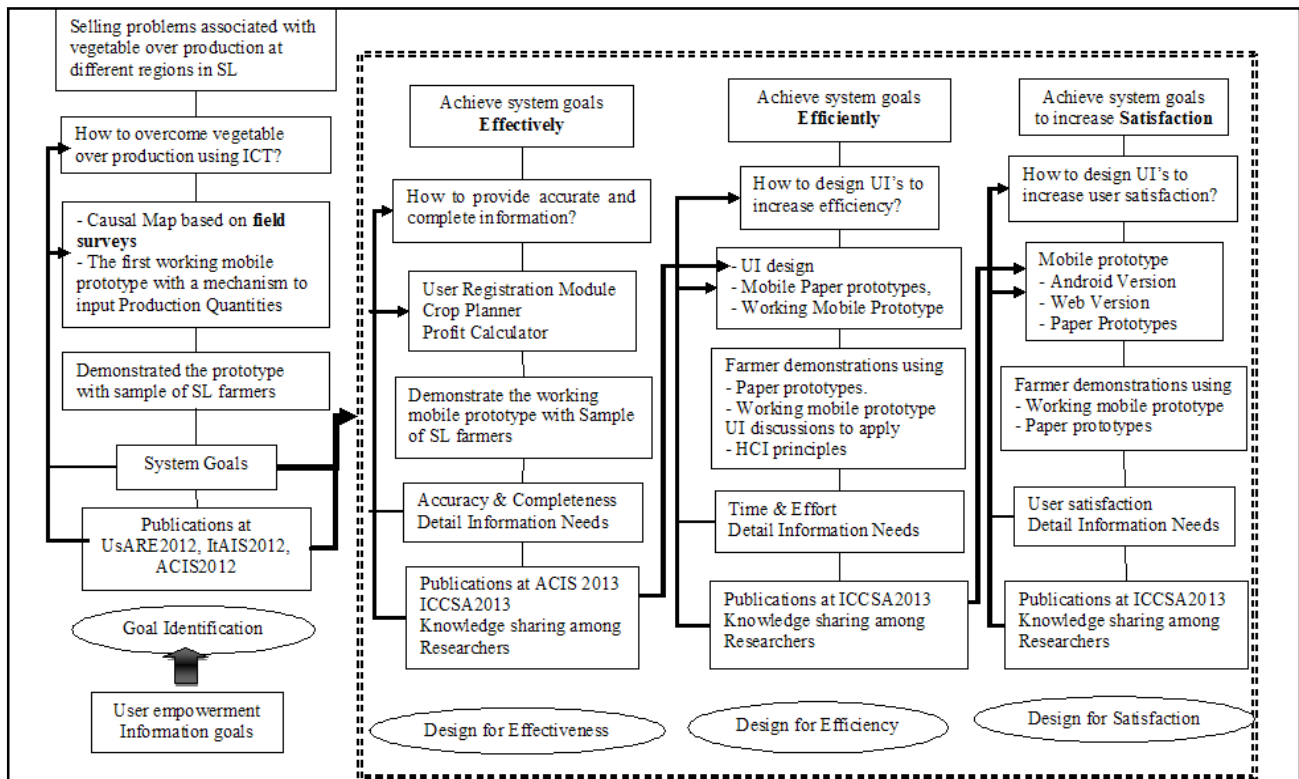


Fig. 2 DSR process to capture user requirements and design for usability and accessibility

Problem identification and motivation is the stage where a specific research problem is identified and importance of the solution is justified. Resources such as “knowledge of the state of the problem and the importance of its solution” [25], are required at this stage. Based on the problem identified next is to identify the main objectives of the solution. Knowledge with respect to the problem, existing solutions and its importance is used to infer the objectives. Objective of a solution will then transform to an artifact within the phase of Design and development. Artifact produced at this stage could include construct, models, methods or instantiations [29]. Once an artifact is created its efficacy to solve the problem is demonstrated by using methods such as experiments, case studies, and proofs [25]. The results observed in demonstration stage are further evaluated to check whether the objective of the solution is achieved successfully. Based upon reflections and feedback this would iterate as shown in Fig. 1 to increase the efficacy of the solution. The knowledge gain through traversing these steps will be communicated further to the research community and other relevant personals. Communication is another added benefit in DSR. Through communications we could further receive feedback on the solution and its efficacy. This knowledge would further feed to align the objectives and to enhance the artifact.

On reflection in our study, as shown in Fig. 2, we have successfully iterated through four DSR cycles to find a solution to the problem associated with vegetable over-production in Sri Lanka. This problem required an innovative ICT based solution. The characteristics such as ad-hoc nature, lack of user exposure to ICT, user unawareness to system requirements made the identification of the solution a much harder task. However, within the first iteration of DSR we succeed in identifying the user requirement goals. In addition to the requirements we further identified the need of user empowerment. This need initiated several DSR cycles in which we achieved effectiveness, efficiency and user satisfaction. Thus, through series of iterative cycles in DSR methodology we were able to derive the functional as well as usability requirements for a problem where there was no prior ICT based solution or clear set of processes that can be enhanced by ICT. This was possible due to the bended techniques of SE and HCI used within the DSR cycles.

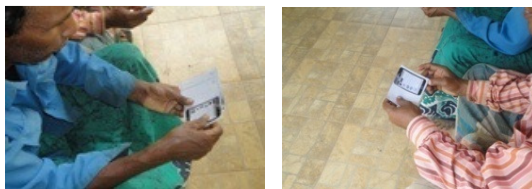


Fig. 4 Farmers evaluating the paper prototypes

In addition to traditional surveys and interviews, we iteratively generated the user requirements through the use of causal maps and scenario transformation methods. Further, grounded on initial requirements, we designed the first

mobile prototype to gather deeper requirements. Both paper-based and functional prototypes were used during the surveys to acquire feedback from the end users of the system.

The Fig 3 and Fig 4 are two instances where we demonstrated the system to farmers using the paper-based and the functional prototype of the proposed solution respectively.

Paper-based prototype was designed to gain more grounded user requirements and feedback for the proposed solution. This enabled us to rapidly incorporate requirements to the design. We traversed through design, development, demonstration and evaluation phases in DSR methodology to refine the prototype. Moreover, these were used to design the real working mobile prototype. This gave a real look and feel to the solution so that users found easy in expressing their requirements. As such we incorporated incremental development techniques described in SE [30], throughout the DSR cycles to speed up the design and development process of the mobile artifact. Further, this approach enabled us to design each of the usability aspects rapidly. As shown in Fig. 2 we iteratively concentrated on how the design goals can be achieved efficiently, effectively and satisfactorily.

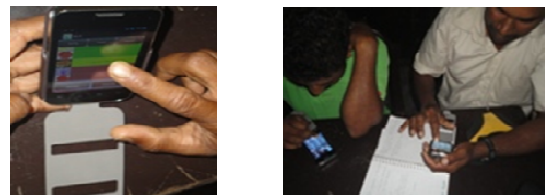


Fig. 3 Farmers evaluating the working mobile prototype

Visual interfaces in this regard played a huge role in enabling us to achieve such goals. These were used constantly during our field visits except for the initial investigations of the problem identification stage. We observed that with these instruments the users trend to provide useful requirements enhancing user participation. As depicted in Fig. 2 in each DSR cycle the demonstrations and evaluations were carried out with the real users of the system.

Focal point of our work was the user. Thus, our research facilitated User Centered Design (UCD) [31] and throughout the methodology we gave priority for the experience of the users. As stated in ISO standard 13407, UCD is “characterized by: the active involvement of users and a clear understanding of user and task requirements; an appropriate allocation of function between users and technology; the iteration of design solutions; multidisciplinary design”. Thus, the DSR framework in this regard was a better framework to facilitate such active user participation to identify the user and their requirements. It is also obvious that having constant interaction with users can make them aware of the solution to a great extent.

The following section provides our reflections on advantages and short comings of the overall development methodology that evolved from this research project.

A. Advantages

The problem we dealt greatly differed when compared to usual software engineering projects. We heavily depended on the user to get a clear understanding of the problem domain. But we were unable to ask users about possible ICT based solution or the requirements to develop such a solution as the users were not aware of the possibilities. However, constant interactions with the users facilitated throughout the DSR process enabled us to identify their expectations and goals. Visual interfaces used in latter stages, enabled us to communicate with farmer successfully. Through these methods we succeed in arriving at a realistic solution. Farmers also found that this is an easy mechanism in providing requirements more freely. We observed in the later part of the project the farmers proactively expressed the requirements compared to early stages of our research. The incremental techniques used throughout the DSR process led us to easily accommodate the evolving requirements with less effort.

Above all, blended nature of several techniques within a DSR framework differentiates our work with the rest in the literature [26, 28, 29]. Based upon the findings of the first DSR cycle we were forced to plan three more DSR cycles to meet usability characteristics. Thus, while gathering user requirements the methodology enabled us to meet the usability aspects of the designed solution. This is an achievement since today most of the designs fail due to the lack of focus on usability aspects. Thus, our study will further contribute to the DSR knowledge repository for the future IS researchers.

Further, the DSR framework employed in this research enabled us to share the experience and knowledge within the different user groups ranging from end user, developers, designers and researchers. The gap between the extremes of end user and researcher were minimized in this work evident from the success derived in this research. Further it helped the research team spread over four continents to share their expertise to derive the solution.

Thus, for problems of this nature we could follow the steps illustrated in Fig 5. However, since we have applied and tested for only one problem in the near future we are planning to evaluate the applicability in other domains such as healthcare and fisheries to extract requirements to design better ICT based solutions. Moreover, the method that we suggested in this paper focuses on usability aspects from the beginning. Thus, we argue that this would increase the success in designing any type of ICT based solution even the stakeholders are more familiar with the requirements.

B. Short Comings

However, to blend different techniques the research team should have expertise in a wide range of techniques. In our case through the voluntary knowledge sharing happened across a large research team spread over four continents we

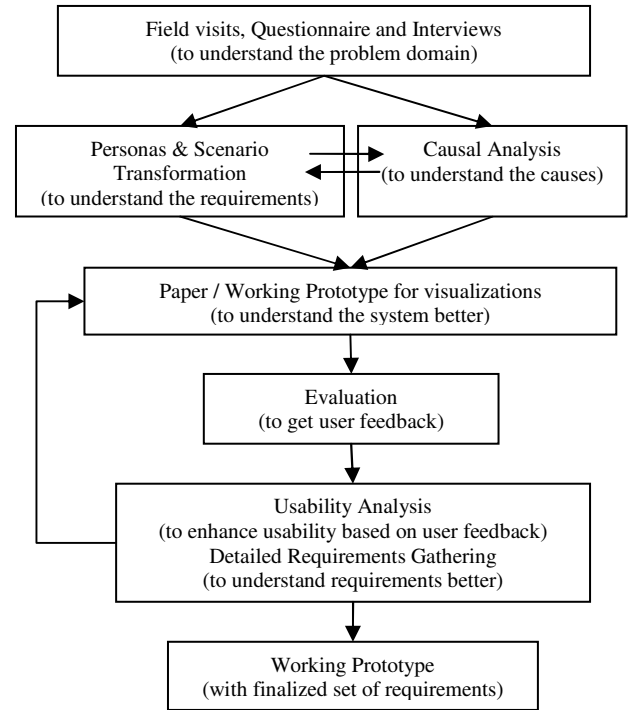


Fig. 5 Process steps followed in this research

had access to required expertise. In the absence of funds this is an unrealistic attempt if the researchers are not voluntary sharing time and resources.

Further, in the absence of active user involvement the method would also fail if they are not willing to share experiences. Further it would also be an issue if they are not willing to spend their valuable time in evaluations.

VI. CONCLUSION

Advances in ICT has resulted in designing innovative solutions for various challenges that different sectors undergo in time to time. Identifying this innovative ICT based solution for a vague problem in the absence of proper hands-on experience in such systems is a challenge. Presence of an ad-hoc nature of the business process adds to the complexity of deriving the requirements.

We solved such a problem successfully by blending a range of techniques using DSR methodology. We found that these cycles can be grouped as identifying goals, designing for effectiveness, efficiency and satisfaction ideally aligning with usability principles. Further, we present an approach derived from this research as shown in Fig 5, which can be used for usability driven requirements gathering and application development when dealing with a wide range of software systems.

This work was done by a research team spread over 4 continents. This DSR based blended approach helped this distributed team to effectively contribute their expertise in different SE and HCI techniques to arrive at a successful solution. Though this approach evolved to solve vague problem it can be used to enhance the usability of other software applications as well.

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