

# A Systematic Approach to Requirements Engineering Process Improvement in Small and Medium Enterprises: An Exploratory Study

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**Abstract.** Requirements Engineering (RE) studies have demonstrated that requirements errors affect the quality of software developed, making software requirements critical determinants of software quality. Requirements Engineering Process Improvement (REPI) models have been provided by different authors to improve the RE process. However, little success has been achieved in Small and Medium Enterprises (SMEs) software companies especially in transitional countries such as Uganda. This study reports on an exploratory study which provides insights into current RE practices in four Ugandan SME software companies, critical success factors and challenges that impede REPI. As a result a Systematic Approach to REPI has been designed following the design science approach. It provides guidelines and steps for SMEs in improving their RE processes.

**Keywords:** Requirements Engineering, Process Improvement, Software Process Improvement.

## 1 Introduction

Fast changing technology coupled with increased competition is placing a lot of pressure on software development process [9]. One of the most crucial parts of the software development process is requirements engineering (RE); and the process of developing new software products always starts with some kind of needs or wishes. The wishes and needs can be of help in finding the requirements that describe the properties and functions of the new software product. Discovering, documenting and maintaining requirements are often described as *requirements engineering* [31]. Effective RE lies at the heart of an organization's ability to produce software products that can meet the needs of the customers yet keeping pace with the rising wave of complexity [9]. The software industry in most countries is composed of Small and Medium Enterprises (SMEs) [18]. This study focused on SMEs mainly because they form the biggest number of software companies in developing countries and yet they produce important products for their clients [24]. Because SMEs are small in nature, then process improvement can easily be achieved through SMEs' flexibility, fast

reaction time and enhanced communication between members. In the Ugandan context a *Small Enterprise* is defined “as an enterprise employing maximum 50 people, annual sales/revenue turnover of maximum Ugandan Shillings 360 million and total assets of maximum Ugandan Shillings 360 million”; while a *Medium Enterprise* is defined as an “enterprise employing more than 50 people, annual sales/revenue turnover of more than Ugandan shillings 360 million and total assets of more than Ugandan Shillings 360 million” [29]. In the software industry, a *small organization* is defined as one with fewer than 50 software developers and a *small project* is one with fewer than 20 developers [18]. RE is a very important phase of the software process as errors at this phase inevitably lead to later problems in the system design and implementation [15]. RE can lead to better quality in software and systems development processes [16, 26]. It’s only with efficient RE that the development process can be controlled and directed in terms of appropriateness and cost-effectiveness of the solution produced [9]. The main aim of a RE process is to come up with a set of necessary, verifiable and attainable requirements, which are acceptable to all the relevant stakeholders [26, 19].

The need to improve the RE process has been recognized for some time now and RE community has witnessed the emergency of models and standards for Requirements Engineering Process Improvement (REPI) and assessment. For example, the *Good practice guide* [27] gives basic guidelines on how to improve the RE process. However, even when the framework has been useful, it was intended for safety-critical domain project, hence lacking adaptation to different domains [30]. It is also too general and complex for SME software companies. The *Flexible and Pragmatic RE* framework for SMEs [22] aimed at providing a framework for RE improvement in SMEs that is more adaptable to support more domains and improve support for small, incremental improvements of the RE process. The *Requirements-Capability Maturity Model* [1] suggests key requirements practices within a maturity framework. Its main objective is to guide software practitioners to relate processes to goals in order to prioritize their requirements process improvement activities. However little progress has been registered in SMEs using these models in improving their RE process as witnessed by the continued failures in these companies

To this end there is a need for SMEs to access a systematic and reliable approach to REPI. In other words, what are the challenges for REPI in SME software companies, and how can these be used to derive recommendations and requirements that can be used to design a systematic approach to REPI in SME software companies? [33] define *Systematic process improvement* as a goal-oriented measurement and controlled way of introducing process change, with predictable outcome in terms of quality, time and productivity

Thus, to put our research in context, we looked at the state of art of SMEs in section 2. In section 3, we describe the research approach followed in order to undertake the exploratory study and later the design of the systematic approach. . In section 4, we describe the exploratory study in which the current practices with respect to REPI in Ugandan SME software companies were investigated and analyzed. We also present the derived requirements that lead to the design of the actual systematic approach to REPI for SMEs in section 5, and finally provide a way forward on future prospects of this research.

## 2 State of the Art

There is scanty literature about RE processes in SMEs; this is because they possess unique characteristics that originate from their make and ownership. For example [14] argues that requirements practices in SMEs are dependent on individuals implementing them. SMEs have got specific problems due to their size and the budget constraints under which they operate, their maturity level in software engineering is very low, little resources to consider quality and process improvements, very few SMEs document their requirements and there are no clear ways of RE process verification and validation [10]. [28] state that SMEs do not emphasize training, have pressing deadlines and so little time is spared for process improvement, SMEs have a simplified software process lifecycle where emphasis is put on development and testing only, SMEs also lack control procedures, project management and planning skills as well as risk management. [18] argues that SMEs cannot measure the process progress and benefits that accrue from such processes.

Many SME software companies are interested in improving their RE processes because of their confidence that RE can be the key to developing successful software systems [18]. However, SMEs find it difficult to implement these process improvements because they cannot bear the cost of implementing these REPIs as well as the limited resources and the strict time constraints in which they operate [18]. A survey of twelve SMEs in Finland reveal that SMEs management are not aware of the available REPI methods but there is desire to start them [20]. [22] argues that where SMEs have in place RE process, it's always very difficult to improve such practices because it has an economic implication to the organization. [10] found out that the most relevant topics to SMEs were requirements modeling, improvement of requirements document, inspections, and tools. In [16] field study, seven key factors were identified as critical to a successful RE process improvement effort and these are package consideration, managing the level of detail of functional process models, examining the current system, user participation, managing uncertainty, benefits of case tools and project management capability. The driving factors in SMEs for RE process improvements are the problems with testing and ISO 9001 certification as well as competing for big contracts with bigger software companies and yet the problems hindering effective RE process improvement in SMEs are the small budgets and tight project schedules. Demonstrated benefits of RE process improvement like the ones in [2] are a fundamental step towards encouraging SMEs to start RE process improvements [10].

Software development processes in Ugandan SMEs are still low with a few cases elaborating the RE processes. Therefore the situation and challenges facing Ugandan SMEs is not different from that discussed above. But perhaps it may even be worse in some cases.

## 3 Research Approach

In order to understand the REPI current practices in Ugandan SMEs from which the systematic approach to REPI was designed; we followed the design science (DS) approach. Design science is fundamentally a problem solving paradigm and therefore

seeks to produce constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations [8]. The created artifacts extend the boundaries of human problem solving within organizational capabilities [8] and are tangible recommendations that enable IT researchers to tackle the problems inborn in developing and deploying information systems within organizations. We chose design science research method because of its ability in solving practical problems that have besieged the Information system arena for some time by creating successfully IT artifacts [23]. To achieve our research goal, we followed the design science research process model suggested by [23]. This model was used because it provides a nominal design science research process with a template for conducting applicable and precise design science research with six clear steps and it was tested and verified using RE case studies, the subject matter of this research [23]. The suggested six steps for conducting and evaluating good design-science research that were used in this research are;

*Problem identification and motivation;* The problem in this research was the lack of a systematic approach to RE process improvements in SMEs. This is due to the inadequate RE processes being used. *Objectives of a solution;* The main objective of this research was to understand the challenges impeding REPI in SMEs and come up with requirements from which we developed a systematic approach for improving RE processes and practices in SMEs. *Design and development;* in this step a literature review was conducted and corroborated with data from the field studies in the selected cases. These led to appropriate requirements for the design of the systematic approach to RE process improvement for SMEs. *Demonstration and Testing;* We planned to demonstrate the systematic approach to the selected cases and get their feedback about the new approach. *Evaluation and validation;* We planned to evaluate and validate the systematic approach in the selected cases against recommended design science value criteria. Questionnaires and interviews will be used in evaluation and validation of the new approach. *Communication;* Presentation of findings and the systematic approach other relevant audiences like SMEs' management, conferences and different reports.

Our exploratory study findings and analyses are based on the data collected through interviews, questionnaires and existing requirements documents. The cases for this study were purposively selected so as to represent different application domains, experiences in software development and company sizes in Uganda. These cases are operating in a wide range of application domains and have been in business between 5 to 10 years which gives them the necessary experience in the RE area. The respondents were software developers, system analysts, project managers as well as system administrators. These SMEs employ five to thirty people.

*Case 1: Makerere University Business School (Socket works project).* This project aimed at developing an Education Information Management System to be used by the school. Its key areas included; requirements elicitation, analysis, design and implementation. It provided respondents in these specific areas of RE. *Case 2: Department of Innovations and Software Development (DISD), Faculty of Computing and Information Technology, Makerere University.* It focuses on the growth of software conception, design and development capacity at the Faculty. DISD believes in the development of local capacity to build and exploit ICT innovations in the Country. It

is also involved in different external and internal projects ranging from Business Information Systems to web based systems.

Case 3: *Crystal Clear Software Ltd.* Its mission is to deliver high quality, user friendly and tailor made business software for her clients. It is the sole developer of Loan Performer software. This software is a database for recording and evaluating microloans. Case 4: *Software Factory Ltd.* It deals in a range of solutions from Business Information Systems to Web Based Systems. RE is one of the areas emphasised in this SME in order to develop quality software for their clients.

## 4 Field Study and Analysis of RE Process and Practices in Ugandan SMEs

The findings of this study are based on the data collected through observations, interviews and questionnaires that were issued to the different experts in the area of requirements engineering. The purpose of the interviews was to gain more information on how practitioners defined and managed requirements in practice as well as the strengths and weaknesses of the existing RE practices and the challenges they faced in REPI. Fifty (50) questionnaires were given out to purposively selected respondents and only 30 informants responded giving a 60% response in the four SME software companies selected. Collected data was categorized, quantified, coded and arranged in themes according to RE practices, REPI challenges and recommendations.

### 4.1 Current RE Processes and Practices in Ugandan SMEs

To get an overview of current RE practices and improvement needs, interviewees with a company-wide role and knowledge of high level RE practices and involvement were sought. The outcomes were assessed using standard RE process practices suggested in the Requirements Engineering Adaptation and IMprovement for Safety and dependability (REAIMS) maturity model [27] and Flexible and Pragmatic RE framework for SMEs [22] due to the fact that they spell out the main activities of a RE process.

**Table 1.** Current RE processes and Practices in Ugandan SMEs

RE Processes and Practices	Frequency	Percent
Elicitation	8	26.7
Elicitation, analysis, specification, validation	3	10.0
Elicitation, analysis, specification, validation, verification	2	6.7
Elicitation, analysis, specification	8	26.7
Elicitation & analysis	6	20.0
Requirements documentation	1	3.3
Requirements negotiation	2	6.7
<b>Total</b>	<b>30</b>	<b>100.0</b>

From table 1, the results revealed that SMEs were involved more in requirements elicitation, analysis and specification (26.7%) as compared to documenting their requirements (3.3%). This shows that these SMEs were acquainted with the first four stages of RE process suggested in [32, 22]. We also observed that there were no SMEs involved in requirements traceability and requirements change management. This implies that the SMEs could not validate the requirements against their sources nor in a clear position to manage requirements that keep changing during the course of the RE process. As it's always the case with SMEs, little documentation (3.3%) of requirements was found in the case studies. This is in line with [10] where requirements documentation is among the priority topics for the workshop. This implies that SMEs did not prepare requirement documents; this may be due to their tight schedules and lack of resources and skills to document the requirements. No SMEs were found to be using automated tools to support the RE process. This was attributed to lack of awareness (knowledge) about the availability and use of such tools; some SMEs thought that these tools were for large organizations and expensive for small ones. This is divergent from [20] who had SMEs with similar roles but were using automated tools to support their RE processes. These results revealed that the Ugandan SMEs were still at the lowest level of the RE process maturity, where the RE process is not explicitly defined, no standards for requirements documentation and requirements description [27]. The preceding observations were further analyzed to establish whether SMEs had a defined REPI approach as seen in table 2. . From table 2, we observed that majority of the SMEs (66.7%) didn't have a defined REPI approach; and when asked why majority (53.3%) responded that they were not aware (knowledge) of how to define one (see table 3). Meanwhile, 33.3% had a defined RE process approach; though it was customized by respective organizations.

**Table 2.** Defined REPI Approach

<b>Approach</b>	<b>Frequency</b>	<b>Percent</b>
<b>Yes</b> (Defined Approach)	10	33.3
<b>No</b> (Not defined Approach)	20	66.7
<b>Total</b>	<b>30</b>	<b>100.0</b>

Majority of the SMEs (66.7%) did not have any specific approach to REPI. This was largely caused by lack of knowledge of the improvement models available for use. This further indicates low levels of RE process maturity in these SMEs. This situation is consistent with [10] study in which REPI was among the top topics ranked by the respondents from different SMEs in Germany.

**Table 3.** Awareness of REPI Models

<b>Awareness of RE process Improvement Models</b>	<b>Frequency</b>	<b>Percent</b>
<b>Yes</b> (Aware)	14	46.7
<b>No</b> (Not aware)	16	53.3
<b>Total</b>	<b>30</b>	<b>100.0</b>

Respondents reported that management was not aware of any available REPI models (53.3%) despite their interest in improving the RE processes. Surprisingly the respondents were aware of the benefits of REPI and willing to start any process improvement in order to tap the benefits. However they did not know any REPI models available in practice and a few were using customized models to help in the improvement of the RE process. This was in disagreement with SMEs in [20, 10, and 30] who have used one or two REPI models in their process improvements despite their low levels of software maturity.

**4.2 Challenges and Recommendations to Successful REPI in SMEs**

Based on the above results, we observed that the Ugandan SMEs did have less to none understanding of REPI (see tables 1-3), and thus becoming important to investigate the hindrances and would-be recommendations to their success as represented in tables 4 and 5 respectively. While in table 5, training (36.7%) was reported as the most favored solution to these challenges.

**Table 4.** Challenges to REPI in Ugandan SMEs

Challenges	Frequency	Percent
Lack of User's Involvement	5	16.7
Lack of management support	5	16.7
Lack of Skills	2	6.7
Changing Requirements	1	3.3
Resistance to change	1	3.3
Ambiguous Requirements	9	30.0
Lack of proper Documentation	2	6.7
Measurement of RE benefits	2	6.7
Expensive	3	10.0
<b>Total</b>	<b>30</b>	<b>100.0</b>

From table 4, we observed that ambiguous requirements from the clients were the biggest challenge (30%) faced by the respondents while on the other hand a few respondents (3%) were faced with resistance to change and changing requirements as obstacles to REPI. Summarized, the challenges that face SMEs include:

*Lack of user involvement;* affects the acceptability of the new process in organizations. This study revealed that users are not fully involved in REPIs instead they are imposed on the users. This concurs with [15] who looked at user involvement in process improvement as a very important factor for user acceptance of new processes.

*Lack of Management support;* This challenge affects the availability of the facilities that support any process improvement efforts in any organization [15]. The study revealed that support from management was lacking towards REPI. This was hindering Process Improvements in these SME software companies. This concurs with [11]

were sustainable changes across an organization require management commitment and support at all levels.

*Lack of Skills;* There are generally low levels of REPI awareness in SMEs. SMEs lack the people with the right skills to carry out proper process improvements that can yield benefits to such organizations and yet they cannot use consultants because of their budget constraints [15]. In this study, it was established that SMEs lacked the necessary skills to start process improvements within their organizations despite their interest to start process improvements. This view is also shared by [11] who argues that a process improvement initiative is at risk if the developers, managers, and process leaders do not have adequate skills to carry out process improvement. *Ambiguous Requirements;* Requirements from users are never clear or complete, so the developers are always occupied with correcting and understanding requirements than starting process improvements in the organization. It's reported in [2] that prior to a REPI initiative; requirements were not clearly defined nor fully understood by developers. This was because clients were ambiguous in stating their requirements. In this study, it was established that clients did not state exactly what they wanted from the new system, thus they keep on changing their requirements from time to time. *Expensive;* Given the tight budgets of SME software companies, it's always difficult to spare some funds for process improvements. The study revealed that majority could not carry out REPI because it was very expensive and it concurs with [10] who highlighted small budgets as the main obstacles to REPI in SMEs. *Measurement of RE process benefits;* measurement of the REPI benefits to the organizations implementing the improvement is a problem to SMEs. Its argued in [30] that it's very difficult to measure the benefits of REPI because there is a long time lag between the requirements phase and system delivery to pinpoint how specific RE techniques contribute to a system's success or failure. *Resistance to change;* this can threaten the success of any new REPI. It's stated in [17] that there is a direct relationship between resistance to change and the total amount of change required of individuals. It's pointed out in [12] that people resist change because change initiatives are introduced too quickly and frequently.

The challenges above have impeded successful REPI in Ugandan SMEs; yet can be critical success factors if well handled. It's argued in [15] that managing the above challenges can lead to better management of REPI in software companies.

**Table 5.** Recommendations to REPI Challenges in Ugandan SMEs

<b>Recommendations</b>	<b>Frequency</b>	<b>Percent</b>
Workshops & RE process Documentation	2	6.7
Training	11	36.7
Management Support & Documentation	2	6.7
User involvement	5	16.7
Project Management Skills & planning	4	13.3
RE improvement strategy	2	6.7
Management of changing requirement	4	13.3
<b>Total</b>	<b>30</b>	<b>100.0</b>

From Table 5 above, it was established that most of the respondents thought training (36%) would provide the necessary skills that are lacking in most of the cases visited for REPI. On the other hand, a few respondents opted for management support and improvement strategies to bring about successful REPI in their organizations. Summarized, the recommendations that SMEs suggested include:

*Training*; [28] emphasis the need of training in process improvement in their OWPL model for software process improvement in SMEs. According to [5] education and training helps to promote the good understanding of the RE process to all the people involved in the improvement process and it's considered to be one of the critical success factor for any RE improvement process. Therefore, there is need to adequately train all people involved in the RE process improvement in order to ensure sustained change. [11] suggests that training helps the organization's members to have a common vocabulary and understanding of how to assess the need for change and how to interpret specialized concepts of the improvement model being used as well as to achieve a common understanding of the improvement process. *Management Support and Commitment*; Management support to process improvement can be in form of funding, encouragement, allocation of staff and providing a conducive environment for working [15]. Raising the management awareness and support of RE practices would make it easier to start RE process improvement efforts in organizations and thus eventually raise the RE process maturity in companies [19]. [15] concur that management commitment process is a fundamental requirement for a successful improvement in RE process.

*Change Management*; can help to manage resistance to change by employees during the RE process improvement. This is in line with [2] who suggested change management as a very important factor for RE process improvement where acceptance of new RE practices can be one of the key challenges in RE process improvement.

*User involvement* in the RE process is very important to the success and institutionalization of any system process improvement. Among the stakeholders from whom requirements are elicited are the potential users of the new system and this helps to come up with a useful system that will meet the needs of the users as well as acceptance of such systems [15]. Several authors have also pointed out that RE process improvement should be a team effort (See for example [2, 26]).

*Use an evolutionary improvement strategy*; [26] points out that it is not realistic to expect organizations to invest a lot of time and money in process improvements whose value is difficult to assess. Therefore, they recommend organizations to introduce small-scale improvements with a high benefit/cost ratio before expensive new techniques. [11] aligns with these statements and points out that, instead of aiming at perfection, it is important to develop a few improved procedures and to get started with implementation.

## 5 Design of the Systematic Approach to REPI in Ugandan SMEs

Many scholars have emphasized the importance of critical success factors in enabling any process improvement [15, 25]. Therefore these can help to overcome the challenges from the exploratory study. In performing the REPI, the existing generic steps suggested by [4] are followed to manage/effect the SAREPI requirements, more so

they are considered important in the REPI plan as shown in figure 1. While improving RE process the company (in our case SMEs) should follow the following steps to accelerate change and RE process acceptance across the company [4].

Challenges	Derived Requirements	Adopted step	Output
Lack of user involvement	Support User involvement	Define a simple RE process	Simple and easy RE processes
Expensive	Use of evolutionary REPI strategy	Pilot the new RE process	Unnecessary project risks avoided
Resistance to change	Support change management	Adapt the new RE process	Tailored RE process adapted
Lack of skills	Provide training and education	Create awareness and promotion of the new RE process	New RE process is promoted in the organization
Lack of Management support	Encourage management support and commitment	Integrate new RE process within the software product development lifecycle	RE process integrated in the organization

### 5.1 Requirements for the Systematic Approach

The requirements for the design of the proposed approach to systematic REPI in Ugandan SMEs were derived from the challenges and recommendations observed in the exploratory study. These requirements could be used as measures to overcome the challenges presented in the preceding section. Apart from the derived requirements from the results presented in the preceding sections, we also adopted the steps from the existing generic REPI suggested by [4] to manage the requirements. This is because they are considered important in the REPI plan.

*Support user involvement* – There is a need to support user involvement in REPI if the new process is to succeed and be institutionalized [11]. User should be involve in the assessment of the current state of the RE process in terms of its strengths and weaknesses. This can serve as starting point for REPI. The assessment made we users build a shared understanding of the improvement goals, planning and practical actions for these SMEs [13]. Users should also be involved while *defining RE processes* – This step follows the assessment of the current RE processes and practices. Simplicity and ease of use in REPI can be a determining factor for any RE process improvement efforts. Involving users in defining simple processes and practices makes it very easy for users to learn and work with the new improved processes, as well as integrating new processes incrementally and gradually.

*Use evolutionary improvement strategy* – [27] recommend organizations to introduce small-scale improvements with a high benefit/cost ratio before expensive new techniques. Where SMEs are budget constrained then small incremental processes can help in alleviating the problem. This is enabled through *piloting the new small RE process*, i.e. use the evolutionary improvement strategy while piloting the new RE processes in the organization. This will help in avoiding unnecessary project risks that may be caused by rapid changes in the organization. Improved processes and

practices should be introduced gradually and blended with existing practices. This will help to create RE process acceptance throughout the organization.

*Support change management* –It’s important to manage change so as to minimize employee resistance to new and improved RE processes. This can be done by *adapting the new RE process*, i.e. tailor the improved process to the organization. There is need to set clear, quantifiable and measureable REPI benefits if the process is to succeed [2]. The benefits of the improved process should be known to all the team members involved in the software development process through a proper change management plan. The new RE process should be adapted to the needs of the organization and be integrated in the daily routines of the organization.

*Support training and education* – education and training helps to promote the good understanding of the RE process to all the people involved in the improvement process [5]. It’s considered to be one of the critical success factors for any RE improvement process. This can be enabled by *creating awareness and promoting the new RE process*. This involves usage of the new RE process benefits to promote its use in the organization and persuading software product development teams to adopt the new RE process and secure the support of senior management. Communicate these practices through face-to-face discussions, staff meetings and newsletters so that everyone in the organization is informed. Organize training and education about the new RE processes to the employees so as to eliminate any chances of resistance to change to the new RE processes.

*Encourage management commitment and support* – Management support to process improvement can be in form of funding, allocation of staff and providing a conducive environment for working [15]. This can be done by promoting systematic use of the new processes throughout the organization.

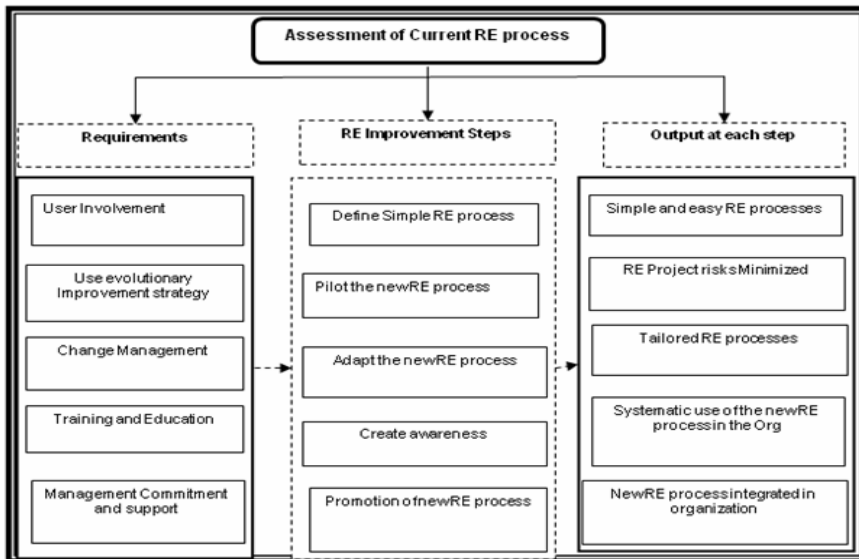


Fig. 1. Systematic Approach to RE Process Improvements (SAREPI)

## 6 Conclusion and Future Work

In this study we looked at the RE process practices and how these can be improved in order to minimize the number of information system development failures as a result of the RE process. This led us to look at the current state of SMEs from which we established the challenges they face in RE process improvement, majority of which come from the size and characteristics of SMEs as small budgets, tight deadlines, lack of skills and trained personnel, management reluctance to support the endeavor as well as unclear requirements from users that keep on changing from time to time. We also established recommendations from the SMEs which we used to derive requirements (support user involvement, use evolutionary improvement strategy, support change management, encourage training and education and encourage management support) for the design of the systematic approach to REPI in SMEs that has been lacking for some time now and especially in Uganda. To operationalise the REPI requirements, we also co-opt the REPI steps as seen in the discussion above which should, if well addressed lead to effective output(s). This approach is a methodical approach that is learnable and understandable through a step by step procedure. Therefore it is very important to SMEs that are unable to improve their RE processes due to different reasons, thus should enable these companies to improve their RE processes systematically. However, during the exploratory study we noted that most of the cases visited had little to none defined RE process, though some SMEs were using customized ways of requirements development. It was hard to assess such cases using the more common known RE improvement and assessment models. More so this research focused on exploring possible approach to systematic improvement of requirements engineering processes in SME, thus far as future research, we propose to empirically validate the designed systematic approach in order to verify if it indeed improves the RE process in SMEs.

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