Improving the Requirements Engineering Process through the Application of a Key Process Areas Approach

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Abstract

The current software process improvement (SPI) standards have no specific section referring to requirements engineering (RE) process and they broadly treat it as a single activity in the overall development process. The RE process plays an important role in the software development process and its importance demands that it be recognized as a process in its own right and not simply as a phase of the software life-cycle. Research shows that in order to produce quality software greater attention must be given to the improvement of RE process. In this paper five key process areas (KPAs) have been identified from the research literature in order to improve the RE process. First, to support a goal-based approach in the RE process; second, to support the incremental and cyclical behaviours in the RE process; third, to encourage stakeholders involvement in the RE process; fourth, to support the management of RE process and fifth, to define a planning phase for the RE process. This research project aims to show that quality requirements will follow when the RE process supports these five KPAs. To implement these KPAs, a requirement elicitation, analysis and validation method (REAVM) is proposed. A framework has been developed from the research literature in order to evaluate the REAVM. A case study has also been conducted in order to test and evaluate the REAVM in the real world environment.

Keywords

Requirements engineering process, Key process areas, case study.

1. Introduction

Inaccurate, inadequate, or misunderstood requirements are the most common causes of poor quality, cost overruns and late delivery of software systems (El Emam and Madhavji 1995). Requirements problems are widely acknowledged to reduce the quality of software and to impact on the effectiveness of the software development process (Sommerville 1996). Despite the importance of requirements engineering, little work has been done on developing ways to improve requirements process. Existing standards for SPI, i.e. Capability Maturity Model (CMM) (Paul et al 1993), (Paul et al 1994) and ISO 9000 (Johnson 1993) series standards do not address the requirements engineering adequately. There is no specific section referring to requirements engineering in these standards and they consider requirements engineering as a single activity in the development process. While "The importance of requirements engineering demands that it be recognised as a complex process in its own right and not simply as a phase of the software life-cycle" (Sommerville et al 1997).

In this paper five KPAs have been identified from research literature in order to improve the RE process. This research investigates the research question that: "If the five KPAs are considered in the RE process then the RE process will be improved". In order to address this research question five KPAs have been implemented using a requirement elicitation, analysis and validation method (REAVM). A process-oriented approach has been used as REAVM is divided into five major phases and each process is an organised set of activities, which

transforms inputs to outputs. The objective is to achieve better results in the RE process and enable requirements engineers to develop incrementally a more complete version of the requirements document. A framework has been developed from the literature in order to evaluate REAVM. A case study has also been conducted in order to see the behaviour of REAVM in the real world environment.

In Section 2 of the paper motivation and background is provided. In Section 3 different KPAs are defined. REAVM is described in Section 4 while in Section 5 REAVM is evaluated through framework and case study. Section 6 concludes the paper.

2. Motivation and background

Many software projects have failed because they contained a poor set of requirements (El Emam and Madhavji 1995). No software process can keep delivery times, costs and product quality under control if the requirements are poorly defined (Sommerville et al 1998). In order to produce software, which closely matches the needs of an organisation, an application domain and the stakeholders, great attention must be given to the RE process (Niazi 2000). The RE process plays an important role in the software development process. The objective of a RE process should be to develop a set of necessary, verifiable and attainable requirements, which are acceptable to all the relevant stakeholders (Kotonya and Sommerville 1998).

Requirements engineering is an important process of the software life-cycle. It has been observed that one can achieve better quality in software and systems development process if the RE process is properly defined (Sommerville et al 1998) and (El Emam and Madhavji 1995). Often the RE process is started without any planning, which results in poor quality requirements and less control over the management of the whole RE process. A mismatch has been observed between the problems experienced by industry and the techniques developed from research in requirements engineering (Sommerville et al 1997). It is also observed that many analysts have limited knowledge of the problem domain, which also results in poor quality requirements and cost overruns (Kotonya and Sommerville 1998). Some examples of fairly common problems with the RE process are as follows (Sommerville et al 1997), (Kotonya and Sommerville 1998) and (Hall et al 2001):

- Vague requirements
- Undefined requirements process
- Inadequate requirements traceability
- Lack of stakeholder involvement.
- Business needs are not considered
- Lack of requirements management
- Lack of defined responsibilities
- The requirements do not reflect the real needs of the customers
- Requirements are inconsistent and/or incomplete
- It is expensive to make changes to requirements after they have been agreed
- There are misunderstandings between customers and software engineers
- Requirements growth
- Stakeholders communication problems

The fundamental problems in requirements engineering have been identified by many researchers e.g. (Hall et al 2001), (Siddiqi and Chandra 1996), (Nuseibeh and Easterbrook 2000), (Nikula et al 2000), (Morris et al 1998), (Kamsties et al 1998), and (El Emam and Madhavji 1995). To highlight a few of these, Hall et al (2001) discussed the requirements process problems in twelve software companies. Their main findings show that the requirements process is a major source of problems in the software development process. Siddiqi and Chandra (1996) and Nuseibeh and Easterbrook (2000) outlined the ongoing research in requirements engineering and its future directions. Siddiqi and Chandra (1996) mentioned a gap between current research and practice and in order to reduce this gap they

suggested a continuous discussion between researchers and practitioners. Nikula et al (2000) analysed the requirements engineering practices in different organizations. Nikula et al (2000) conducted a survey with twelve small and medium enterprises in order to get some numerical data on the knowledge of current requirements engineering practices and the desire to improve them. They presented the results of an empirical survey showing that the problem is not in the practitioners' lack of desire for improvement but in the management not knowing that many requirements engineering issues can be solved with standard practices that are well documented in the literature. El Emam and Madhavji (1995) described a field study and the results indicate that there are seven key issues of greatest concern that must be addressed in a successful RE process improvement effort: 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 Capability Maturity Model (CMM) (Paul et al 1993), (Paul et al 1994) and ISO 9000 (Johnson 1993) series of standards share a common concern with quality and process management. There is no specific section referring to requirements engineering in these standards. The CMM is a valuable model for SPI but it is very hard to gain benefits when it is applied to the requirements process. Only requirements management is treated in details and is identified as a KPA for level 2 (repeatable) processes. But requirements management is only one area of the requirements process. CMM does not provide any specific section for the other areas of the RE process, i.e. requirements elicitation, requirements negotiation and requirements validation. There is also no particular section to requirements engineering in ISO 9000 series standards and they do not say much about the activities involved in eliciting, analysing, negotiating and validating the requirements

Sommerville et al (1997) and (Sommerville et al (1998) have published the RE process maturity model which has been derived from the existing standards and has three levels, i.e. Level 1-Initial, Level 2-repeatable and Level 3-Defined. This model can be used to assess current RE process and it provides a template for requirements engineering practice assessment. This model does not provide any general methodology for the improvement of the RE process. However, it also does not provide KPAs like CMM but rather it organizes different requirements practices with various deliverables in the RE process.

Requirements engineering is an important process of the software life-cycle. As no current SPI standards adequately address the issues of RE process and they broadly treat requirements engineering as a single activity in the overall development process, therefore, research in the area of RE process improvement lies at the very core of requirements engineering research.

3. Improving the Requirements Engineering Process

The major objective of this research project is to improve the RE process. Because if the RE process is improved, quality requirements can be achieved and the real needs of the stakeholders can be reflected.

Like CMM (Paul et al 1993) and (Paul et al 1994), the following five KPAs have been identified from research literature. This research project aims to show that quality requirements will follow when the RE process supports the following:

- **To support a goal-based approach in the RE process**

Goals are the high level objectives of the business, organisation or system which provide a framework for the desired system (Anton 1997). Goals denote the objectives a system must meet (Nuseibeh and Easterbrook 2000). Goals are useful for organising and justifying requirements. Goals have been introduced into requirements engineering for a variety of reasons, i.e. requirements acquisition, relating requirements to the organisational and business context, clarifying requirements, documenting requirements, dealing with conflicts, assisting the

management of change and driving the initial design (Yu and Mylopoulos 1998) and (Lamsweerde 2001). Goals set an agenda by which requirements are discovered, analysed and documented (Sommerville et al 1998). Normally it is difficult for the stakeholders to fully understand the requirements of the organisation or application domain but with clear goals a good understanding can be obtained. By focusing on goals initially instead of broad requirements, analysts enable stakeholders to communicate using a language based on concepts with which they are both comfortable and familiar (Anton 1997).

- **To support the incremental and cyclical behaviours in the RE process**

Several studies (Potts et al 1994), (Boehm et al 1994), (Sommerville et al 1997) and (Sommerville et al 1998) strongly suggested that the requirements process is cyclical. (Potts et al 1994) have proposed a cyclical model, called the Inquiry Cycle that consists of three iteratively repeated activities: expression, discussion and commitment. (Boehm et al 1994) have proposed a requirements process model based on its spiral model of software development (Boehm 1988), which establishes stakeholders' "win" conditions and includes steps in order to facilitate identification and negotiation of requirements trade-offs. (Sommerville et al 1997) and (Sommerville et al 1998) have also proposed a spiral model that consists of three iterative activities: requirements elicitation, requirements analysis and validation and requirements negotiation.

The incremental behaviour is regarded as the most realistic approach to software development for large-scale systems (Pressman 1997). Incremental behaviour uses an evolutionary approach to development and contains the systematic and the 'development in steps' approach of the traditional project life cycle (Sommerville 1996). Using this behaviour the functionality of the system is produced and delivered to the customers in small increments which avoids the 'Big Bang' effect, i.e. for a long time nothing happens and then, suddenly, there is a completely new situation (Vliet 1993).

- **To encourage stakeholders involvement in the RE process**

In most case the concerned stakeholders are not involved in the RE process and their real needs are not considered in the system (Sommerville et al 1997). Involving the stakeholders in the development process can reduce their fear for example that the development of a software system will result in loss of jobs. It is also possible that if a new system is installed in an organisation without consulting the stakeholders, who would be affected by the system, then they may feel that a new system is unnecessary and therefore they tend to not co-operate in its specification. Stakeholders involvement in the RE process is one of the most important factors that contribute to the success of the project (Rauterberg and Strohm 1994) and (DeBillis and Haapala 1995). With the stakeholders involvement less rework of the documentation items is required, real requirements can be gathered and political conflicts are reduced (El Emam and Madhavji 1995).

- **To support the management of RE process**

During the RE process new requirements emerge and existing requirements change at all stages of the system development process. It is often the case that more than 50% of system's requirements will be modified before it is put into service (Kotonya and Sommerville 1998). The RE process is a learning process, and ideas generated at one point may change at another point. This evolution of requirements throughout the whole software development life cycle has to be managed in order to ensure high-quality specifications. The management includes issues such as information storage, organization, traceability and documentation. Requirements management may look like an overhead in the RE process, but it is usually rewarded by better customer satisfaction and lower system development costs.

- **To define a planning phase for the RE process**

Effective management of a software project depends on thoroughly planning the project (Sommerville 1996). Normally the RE process is started without any planning and the requirements engineers inevitably wish to start very quickly. The RE process will be an unproductive exercise if started haphazardly and without planning. Particular attention should be paid to the planning of the RE process.

4. Implementation of five key process areas

In order to implement the five KPAs a "Requirements Elicitation, Analysis and Validation Method (REAVM)" has been developed. This method has a prescriptive nature because "a good method should be prescriptive enough to be able to recommend what development activity to do next" (Nuseibeh 1994). This method has been derived from the cyclical and incremental models and has an iterative and feedback nature. The reason for the development of a method is that a method is a systematic way of working by which one can achieve a desired result (Wieringa 1996). "A method provides a prescription for how to perform a collection of activities, focusing on how a related set of techniques can be integrated, and providing guidance on their use" (Nuseibeh and Easterbrook 2000). All the identified KPAs are incorporated in this method

The development of a method is heavily dependent on a thorough definition of its processes, roles, activities and interactions. Further recent trends, focusing on process technology, have confirmed that a quality product can only be the result of a quality process (Aliee 1996). Thus a process-oriented approach to method definition has been selected as the basis for this research project. REAVM is divided into five major phases and each phase is an organised set of activities which transforms inputs to outputs. Each phase takes an input, adds value to it and provides an output. The output of a phase is used as an input for the next phase and so on.

4.1.The structure of REAVM

REAVM is derived from the cyclical and incremental models and is divided into five phases (as shown in Figure 1):

- Planning.
- Requirements elicitation.
- Requirements analysis.
- Requirements agreement.
- Requirements validation.

4.2 The cyclical behaviour of REAVM

Figure 2 illustrates proposed cyclical model that has been abstracted from different studies (Potts et al 1994), (Boehm et al 1994), (Sommerville et al 1997) and (Sommerville et al 1998). It is cyclical in that requirements become apparent from successive iterations in the context of the requirements which emerge from previous iterations. Hence requirements which emerge in the later iteration may limit requirements which emerge in the previous iteration. Therefore, requirements may need to be modified in the light of information which emerges later.

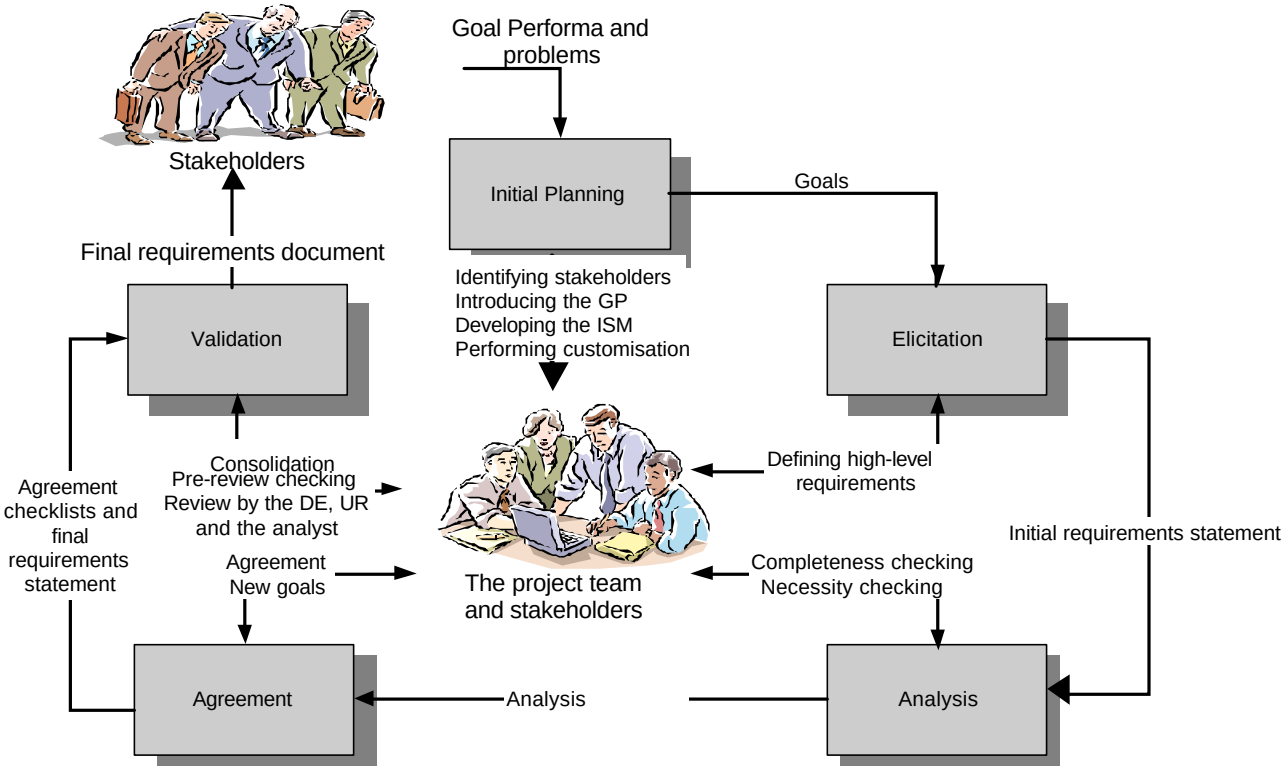


Figure 1: The structure of REAVM

In this cyclical model, five activities are repeated each iteration of the REAVM cycle. This model works at two levels: Firstly, only one goal is considered for REAVM cycle. After first cycle of REAVM, if sufficient information is not collected or some conflicts are still not resolved then the same goal is re-considered for the second cycle of REAVM and so on. Through this cyclical behaviour requirements will become apparent and it is possible that the requirements generated in the later iteration may limit requirements generated in the previous iteration. Secondly, after the completion of first goal then the second goal is considered for REAVM cycle and as mentioned earlier requirements which emerge in the iteration of second goal may limit requirements which emerged in the iteration of first goal. Hence requirements elicited in each cycle of REAVM are validated with the previous elicited requirements for consistency, completeness and feasibility.

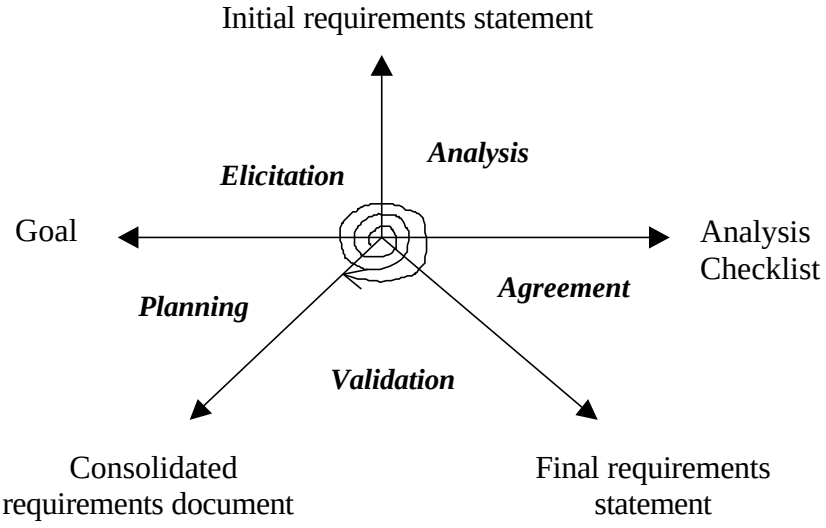


Figure 2: Cyclical behaviour of REAVM

4.3 Incremental behaviour of REAVM

This method assumes that the requirements for large systems are incrementally gathered, analysed and validated using multiple builds as shown in Figure 3. The initial planning for build-1 is performed at the beginning of the project. Further planning is performed as and when required, as new goals can emerge during different phases. The next three phases, elicitation, analysis, and agreement are performed once for each build. The last phase, validation, is performed after each build. This shows the incremental behaviour.

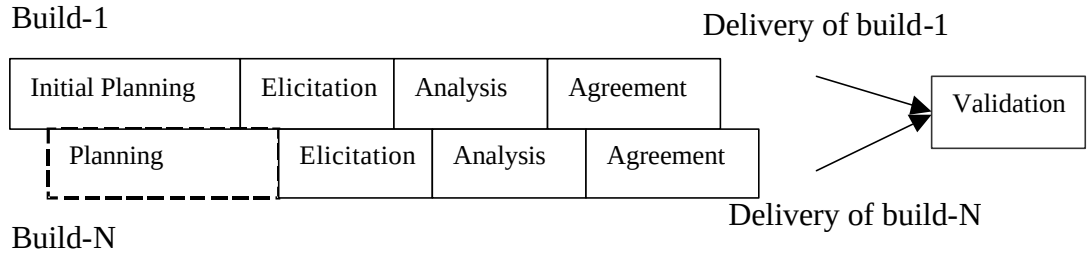


Figure 3: Incremental behaviour of REAVM

4.4 Planning phase

This is the first phase of REAVM. The aim of this phase is to provide some planning for the subsequent phases of REAVM.

Four types of stakeholders are identified during planning phase, i.e. the executive sponsor, the analyst, the domain experts (DEs) and the user representatives (URs). The executive sponsor is the manager or executive who is responsible for making executive level decisions and commitments. The analyst is responsible for different tasks of REAVM. A domain expert is a person who can provide detailed information on a narrow, well-defined topic. They have the best available view of a particular domain area.

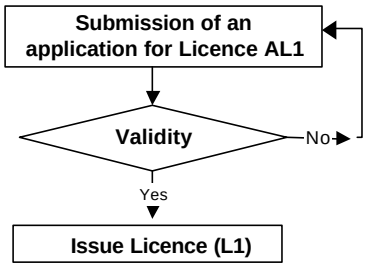
In order to implement goal-based approach, the goal Performa (GP) is introduced in REAVM to establish the goal and the flow of that goal from each DE and UR. According to (Sommerville 1996) simple diagrams, supplemented by descriptions of the system entities, are the appropriate starting points for describing system contexts. The GP is constructed by assuming that the stakeholders have goals in their minds. One example of the GP is shown in Table 1.

In the planning phase different essential tasks are performed by the analyst, i.e. goal identification, goal prioritisation, team organisation, assigning of responsibilities and preparation of different materials to be used in different phases of REAVM. Teams are organised according to the goals. Responsibilities are assigned to different stakeholders for elicitation, analysis, agreement and validation phases. Also some materials are prepared which can be used during different phases of REAVM. This material also contains the question lists to be used during the elicitation phase.

4.5 Requirements elicitation phase

The goals which are created in the initial planning phase are taken as input. The goal which has the highest priority number is considered first for elicitation and so on. The following steps are performed in this phase:

- Defining high-level requirements.
- Determining the scope of the requirements.
- Generation of initial requirements statements.

Goal Number:	6
Goal Name:	Modification of AL1
Description of Goal:	Modification of application for licence (production) AL1
Sources of Goal:	Central Excise Circles, Domain Expert (AL1) and User Rep. (AL1)
Function of Goal:	The activity for collection of excise duty starts with an application for commencement of business, production. The application is lodged with the circle office on prescribed forms (AL1) for issuing of licence
Problems:	The current AL1 form does not contain all the required information
Flowchart of Goal:	

Source Name: Domain Expert (AL1)

Table 1: Goal Performa

The analyst facilitates the group discussions that elicit the requirements. In order to implement stakeholders involvement KPA, the participants are encouraged to bring different ideas and views about different problems. Participants are also invited to express their viewpoints about any of the problems. Different questions are asked from each DE and UR using the lists of questions prepared in the initial planning phase. Every participant is allowed to present his viewpoint, if required.

Through carefully facilitated discussions, the ideas and views about the above topics are presented, examined and refined, so that by the end of the elicitation phase everyone is in agreement. If necessary, interviews can be conducted with those who are not participating in the meeting but they have some relation with the goal under consideration.

At the end of the elicitation phase an initial requirements statement (as shown in Table 2) is generated for each goal by the analyst and is given to each DE and UR for analysis and discussion. It is important to note that in order to manage the requirements effectively each goal has a unique identifier and all the requirements under that goal have their own identifiers. So any requirement under a specific goal can be referred in any requirements document.

4.6 Requirements analysis phase

The goal of this phase is to find problems in the initial requirements statements generated in the requirements elicitation phase of REAVM.

In the requirements analysis phase the following types of checking is performed using the analysis checklist (available from the author):

- Completeness checking.
- Necessity checking.
- General comments.

Stakeholders analysed the requirements for completeness. Completeness means that no requirements that are needed have been omitted, i.e. whether the elicited requirements have covered all of the needs and objectives of the organisation, application domain and stakeholders (Kotonya and Sommerville 1998)? An initial requirements statement can be considered as complete when all of its parts are present and no postponed decision or no "to be defined" statements, still exist. In completeness checking the incomplete requirements are pinpointed.

Stakeholders analysed the requirements to see if the elicited requirements contribute to the business goals of the organisation, i.e. whether the elicited requirements satisfy the needs and objectives of the organisation, application domain and stakeholders. It is also analysed to ascertain whether the elicited requirements are in fact necessary and solve the specific problems.

At the foot of the analysis checklist the stakeholders have to provide general comments about the initial requirements statement. In general comments the stakeholders give their point of view about the elicited requirements and mention whether or not they agree with the elicited requirements, or want further modification. If they want further modification then that modification is specified. They can also mention new goals, if any have emerged during the elicitation and analysis phases.

Goal Number: 6
Goal Name: Modification of AL1
Description of Goal: Modification of application for licence (production) AL1
Sources of Goal: Central Excise Circles, Domain Expert (AL1) and User Rep. (AL1)
Function of Goal: The activity for collection of excise duty starts with an application for commencement of business, production. The application is lodged with the circle office on prescribed forms (AL1) for issuing of licence
Problems: The current AL1 form does not contain all the required information
Elicited Requirements:
***Requirement 1*:** The AL1 form shall be updated to contain all the required information and the new AL1 form shall contain the following production unit information:
Circle name, unit national tax number, unit licence number, unit name, unit address, unit telephone number, unit fax number, unit paid up capital, unit licence expiry date.
Requirement 2: Details regarding ownership:

- If an individual is the owner of the unit, then his national tax number, NIC number, name, address, telephone number, fax number and email address shall be provided.
- If the unit is Registered Firm then the registration number, date of registration, expiry date and issuance authority for the firm shall be provided.

…….
……..
Requirement n: _____

Table 2: Initial requirements statement

4.7 Requirements agreement phase

The agreement phase is the process of discussing the issues/problems pointed out by the DEs and URs in the requirements analysis phase of REAVM and finding some agreement with which all of the stakeholders can live. All the analysis checklists are discussed individually and the objective of discussion is to solve the issues in particular checklist. All the stakeholders are encouraged to give comments on the problems identified and the recommendations made by them in different analysis checklists. Solutions are identified and issues are resolved to the satisfaction of the parties involved. Generally, this will involve deletion of some requirements and making changes to some of the requirements in order to improve them.

In many cases, it is possible that some questions may be raised which cannot be answered, and for which the stakeholders may not agree with the proposed solutions. This means that the information available for the agreement is insufficient. In such cases, the unresolved issues are forwarded again to another round of REAVM.

If some new goals emerge then it is decided in the agreement phase whether these newly emerged goals require some planning or not. If these goals do not require planning then these goals are considered for elicitation. If these goals require planning then they are considered for

planning separately, i.e. these new goals should not be mixed up with those goals whose initial planning has been performed.

This phase is concluded by reviewing with the participants the information collected and the decisions made. At the end of this phase, the final requirements statements (as shown in Table 3) and the agreement checklists (available from the author) are generated and forwarded to the validation phase for validation and discussion.

Goal Number: ___ **Goal Name**: _____ **Description of Goal**: ____ **Final Elicited Requirements:** *Requirement 1*: *Requirement n*:

Table 3: Final requirements statement

4.8 Requirements validation phase

This is the final phase of REAVM. In REAVM only one goal is considered for elicitation, analysis and agreement at any one time. It is therefore possible that some infeasibility, inconsistency and incompleteness may exist when all the goals are consolidated into one document. It is also possible that some previous requirements may change because the customers can change their minds, or even the environment of the system, laws or regulations might change. Therefore, the objective of this phase is to check and remove such infeasibility, inconsistency or incompleteness and to modify the changed requirements to the new requirements.

The final requirements statements generated in the agreement phase of REAVM are consolidated into one requirements document after each cycle or build. Each goal has its own serial number, so using this serial number all the final requirements statements are consolidated sequentially into one document.

The DEs and URs read and analyse the requirements document and look for different problems e.g. changed requirements, inconsistencies, incompleteness and infeasibility. They note different problems in the validation checklist-1 (available from the author). Each reviewer notes the different problems identified by him in a separate validation checklist. They also give recommendations for the solution of identified problems. After the completion of validation checklists-1, each checklist is forwarded to the analyst with requirements document for cross checking.

The analyst reads and analyses the requirements document and each validation checklist-1. By using his knowledge and understanding of the system the analyst looks at different problems and recommendations given in the checklists. He gives comments on them using validation checklist-2 (available from the author).

Finally, these validation checklists are discussed, and agreed actions are performed. If some requirements are incomplete then for those specific requirements the elicitation, analysis, agreement and validation phases can be performed again. If some requirements are inconsistent then meetings are held between the stakeholders, whose requirements are inconsistent, in order to reach agreement and to remove these inconsistencies. If some requirements are infeasible then those requirements are modified or eliminated and if some requirements are changed then those requirements are modified according to new requirements.

5. Evaluation of REAVM

5.1. Evaluation of REAVM using framework

REAVM has been evaluated using the evaluation framework developed from the research literature (Sommerville et al 1997), (Sommerville et al 1998) and (El Emam and Madhavji 1995). This framework has been developed using five main criteria. First, it should be geared to the RE process; second, it should clearly differentiate between the stages of RE process; third, its dimensions should be well used and well known; fourth, it should have basic objective to improve/assess the RE process and fifth, it should incorporate the objectives of this research project. This framework has 4 components and 28 dimensions and provides a very practical framework with which to evaluate the REAVM. Against each dimension, one of the following assessments is made.

- *Fulfils criteria*. This means that the dimension fully describes the process or practice that has a documented standard in REAVM.
- *Partially fulfils criteria*. This means that the dimension partially describes the process or practice.
- *Do not Fulfils criteria***.** This means that the dimension does not describe the process or practice.

As a whole, the REAVM performed well in the assessment criteria using the framework. An overview of the REAVM evaluation using the framework is shown in Table 4. Out of 28 dimensions 18 fulfilled the criteria, 3 partially fulfilled the criteria and 7 did not fulfil the criteria. REAVM fulfilled 64% of the criteria, partially fulfilled 11% of the criteria and did not fulfil 25% of the criteria as shown in Figure 4.

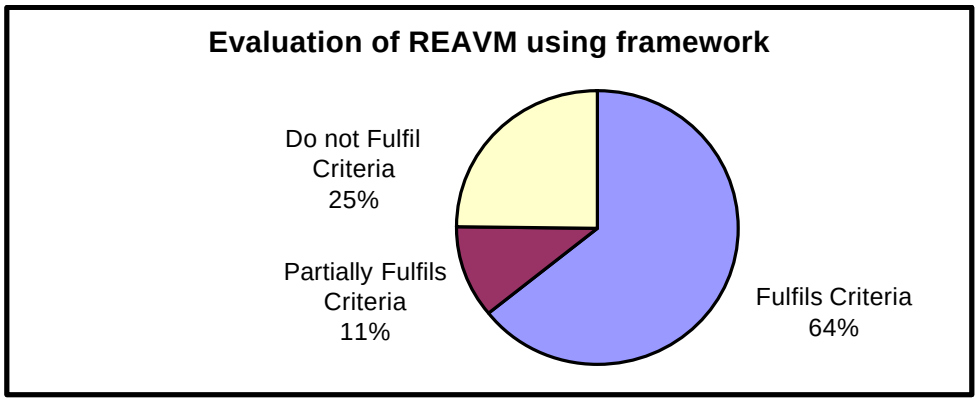


Figure 4: Evaluation of REAVM using framework

In the requirements process maturity model of (Sommerville et al 1997) and (Sommerville et al 1998), in order to assess the requirements process maturity, different points are scored to the specified guidelines, i.e. 3 points are scored for standardized practice, 2 for normal use, 1 for discretionary use and 0 for practices that are never used. The assessment criteria has been adopted from the above model where the requirements process is considered matured if it gets more than 55 points (50%) in the basic guidelines. If roughly 50% is considered an average success criterion then satisfactory results have been achieved.

5.2 Case study

A case study was conducted at the XYZ Company. The main purpose of the company is to enhance the efficiency and effectiveness of the Information Systems prevailing in public and private sectors. This study was conducted in order to test and evaluate the REAVM in the real

world environment. The case study was carried out with three main objectives. First, to test the validity of REAVM. Second, to highlight areas where the REAVM has deficiencies. Third, to show the practicality of REAVM in use. Before commencing the case study the introduction, its purpose and relevant documentation of REAVM were provided to the XYZ Company. Group of 8 people and one team leader were selected for this case study by the authorities of XYZ Company. The team leader communicated with the author through email for one month in order to get good understanding of REAVM. Before commencing the study one week REAVM training was provided to the stakeholders nominated for this case study.

Components	Dimensions	Fulfils Criteria	Partially Fulfils Criteria	Do not Fulfil Criteria	N/A
Elicitation and Planning for the REP.	Recording requirements sources	X			
	Prioritising requirements			X	
	Developing system model		X		
	Identifying stakeholders			X	
	Assigning of responsibilities	X			
	Examining the current system	X			
	Requirements elicitation	X			
	Use business concerns to drive requirements	X			
Sub Total	**8**	**5**	**1**	**2**	**0**
Stakeholders involvement in the REP.	User participation	X			
	Collecting requirements from multiple viewpoints	X			
	Using multidisciplinary teams to review requirements	X			
	Stakeholders communication problems			X	
	Involving the external reviewers			X	
Sub Total	**5**	**3**	**0**	**2**	**0**
Requirements management and documentation in the REP	Defining a standard document structure	X			
	Making the document easy to change	X			
	Uniquely identifying each requirements	X			
	Defining system boundaries		X		
	Managing uncertainty	X			
	Consideration of packages			X	
	Benefits of CASE tools		X		
	Project management capability	X			
	Requirements traceability	X			
	Managing the changed requirements	X			
Sub Total	**10**	**7**	**2**	**1**	
Requirements analysis and validation in the REP	Using checklist for requirements analysis	X			
	Defining validation checklist	X			
	Using interaction matrices to find conflicts	X			
	Use prototyping to examine the requirements			X	
	Assess requirements risks			X	
Sub Total	**5**	**3**	**0**	**2**	
Grand Total	**28**	**18**	**3**	**7**	**0**

Table 4: An evaluation of REAVM using framework

In this case study, 8 goals were collected from the stakeholders. Then these goals were prioritised and teams were organised and responsibilities were assigned to different stakeholders. A separate initial requirements statement was generated for each goal. Each initial requirements statement was analysed using separate analysis checklists. Issues raised in the analysis checklist were resolved using an agreement checklist and a separate final requirements statement was generated for each goal. All the final requirements statements were consolidated into a final requirements document and this final requirements document was reviewed by the DEs, URs and analyst using validation checklists. Finally, sixty-six requirements were generated from these 8 goals.

At the end of this case study, a requirements review process was carried out by the stakeholders who were involved in the case study in order to compare the REAVM with the method used previously by XYZ Company. Author worked as an observer in this process. This process contained four checklists, i.e. requirements elicitation, requirements modelling, requirements verification and requirements management (available from the author). These checklists have been developed using different literature (El Emam and Madhavji 1995), (Sommerville et al 1997) (Sommerville et al 1998) and (Kotonya and Sommerville 1998). Each checklist were jointly completed by all the stakeholders who were involved in the case study and at the end of this process a report was produced which compare REAVM with the standard method used by the XYZ Company. Again the assessment criteria was adapted from (Sommerville et al 1997) and (Sommerville et al 1998). In these checklists 4 points were given to the guidelines which were very well defined, 3 points were given to the guidelines which were adequately defined, 2 points were given to guidelines which were less than adequately defined, 1 point was given to guidelines which were not defined very well and zero point was given to guidelines which were not applicable.

As a whole, the REAVM did not perform exceptionally well when compared with the method used by XYZ Company. A column chart is shown in Figure 5 where REAVM satisfied 70.23% of the criteria and XYZ Company satisfied 55.95% of the criteria. Although REAVM did not perform exceptionally well when compared with the method used by XYZ Company but it was observed that the method followed by XYZ Company has some deficiencies, which have been overcome in REAVM. Some of the important properties which have not been considered in the methodology followed by XYZ Company are: consideration of sources of requirements for the traceability, consideration of goals for the derivation of requirements, management of new goals, unique identification of requirements for effective management, classification of requirements and use of checklists and interaction matrix for the verification of collected requirements. These deficiencies have been overcome in REAVM where sources of requirements have been recorded in REAVM using GPs, a goal-based approach has been used in REAVM in order to derive, analyse and document different requirements, new goals have been managed by the use of checklists, requirements have been classified into related goals, different checklists have been used in order to validate different requirements. In addition to all these improvements stakeholders actively participated in all the phases of REAVM. A planning phase has helped in the management of the whole REAVM process. Incremental and cyclical behaviours have helped in the generation of requirements in steps and avoided the 'Big Bang' effect. Requirements management has given more control to the monitoring and effectively generating different kinds of REAVM statements.

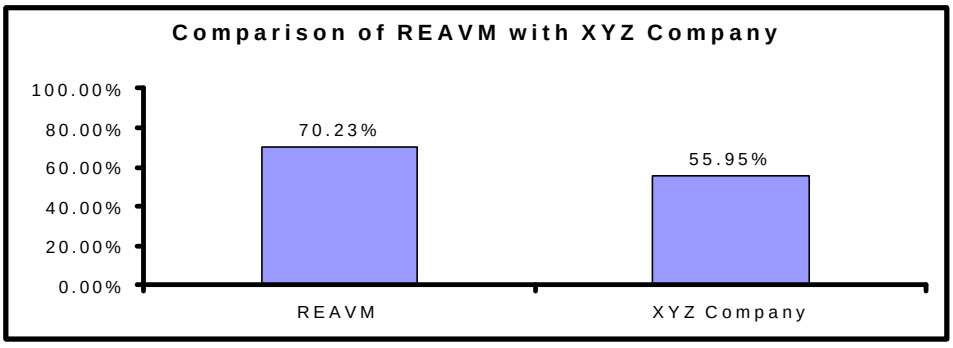


Figure 5: Comparison of REAVM with XYZ Company

6. Conclusions

For the improvement of RE process five KPAs were considered and it was believed that if these KPAs have been considered then the RE process will be improved. To check whether RE

process has been improved or not it is important to check the results, which have been achieved by using the framework and by conducting the case study. By using the framework, REAVM achieved satisfactory results but in case study REAVM did not perform exceptionally well when compared with the method used by XYZ Company.

As a whole REAVM performed fairly well. It is believed that the KPAs selected for the improvement of RE process are the best cluster in order to enhance the capability of the RE process but the way these KPAs are structured into REAVM need further refinement and improvement. It is also believed that REAVM can be further improved through large-scale case studies.

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