A Systematic Study on Requirement Engineering Processes and Practices in Mauritius

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Abstract— Requirement engineering processes have been used for many years in software development. The processes consist of four stages namely elicitation, analysis and negotiation, specification, and validation. The appropriate use of the different stages for a given project, and tailoring the stages to a specific requirement has been a challenge since requirement engineering varies from organization to organization. Nowadays, more than ever, software development projects are geared towards failures due to poor requirements. This paper analyses the requirement engineering processes across different organizations with the aim of identifying the difficulties that are encountered in the requirement engineering processes and the gap that exists between theory and practice. As resolution, solutions have been proposed to overcome the difficulties encountered and to bridge the gaps resulting in enhanced requirement engineering and potentially much better software.

Keywords— Requirement Engineering Processes, Requirement Elicitation, Requirement Analysis and Negotiation, Requirement Specification, Requirement Validation

I.   INTRODUCTION

Requirement Engineering (RE) is the key and essential activity in software project development as requirements are like blueprints for any software. It is the process of identifying stakeholders, eliciting their needs and/or expectations, analysing their requirements with negotiations, documenting and validating the requirements that will eventually be used for implementation [1] [2]. RE is also the most difficult and demanding task since inappropriate requirements eventually lead to many project failures in terms of cost, schedule, quality, failure to deliver all the system requirements and customer dissatisfaction [5].   There are different ways of gathering requirements and various organizations have established their own [3]. Difficulties always arise during RE processes and it is worth considering that there is a gap between theories and what is happening in practice that is in real-life [4].

II.   REQUIREMENT ENGINEERING PROCESSES

The Requirements Engineering Specialist Group (RESG) of the British Computer Society defines requirements engineering as *"...a key activity in the development of software systems and is concerned with the identification of the goals of stakeholders and their elaboration into precise statements of desired services and behaviour."* [18] Requirement Engineering is one of the most important tasks in software development. Requirements are the foundation of software and requirement engineers come across numerous challenges to develop successful software [10]. Many problems arise in software development due to wrongly defined requirements [5] which are:

- Schedule slippage
- Cost overruns
- Poor customer satisfaction
- Software does not meet expectations
- Errors in software lead to poor quality deliverable
- Increase cost of maintenance due to rework

Requirement engineering is comprised of four pillars as follows:

A. Requirement Elicitation

Requirements elicitation can be broken down into the activities of fact-finding, information gathering, and integration [6]. Research has shown that the potential impact of poorly formulated requirements is substantial. In a previous research, Boehm suggested that requirements, specification and design errors are the most numerous in a system, averaging 64% compared to 36% for coding errors [6].
Classification of key requirement elicitation challenges [6], [8], [9]-[12]

1) Problems of scope: The boundary of the system is ill-defined whereby unnecessary information may be given, or necessary information ignored.

2) Stakeholder confusion: There are problems of understanding among stakeholders such as incomplete understanding of needs that may also be conflicting and/or vaguely expressed.

3) Requirement volatility: Requirements evolve over time, either because of changing needs or because of changing perceptions by the stakeholders. As a consequence, stakeholder expectations might go unexpressed and unfulfilled.

4) Identification of stakeholder: Potential stakeholders need to be identified since they are directly or indirectly affected by each phase of the project.

5) Lack of stakeholder's involvement: Requirements are defined by an intermediary without directly consulting or involving the key stakeholders who will eventually use the software being developed.

6) Ineffective requirement elicitation techniques: When requirements engineers lack knowledge of the different elicitation methods, activities related to requirements will lead to wrong specifications that will never meet the stakeholder' expectations.

B. Requirement Analysis and Negotiation

Requirements analysis and negotiation is one of the most crucial process in requirements engineering since it moulds the shape of the desired software end product. During this phase, conflicts are inevitable since requirement engineers deal with many stakeholders who have their own perspectives, concerns, priorities and responsibilities. Research shows that this phase is important since it is correlated with the quality of intermediate deliverables such as the requirements document which in turn is correlated with the quality of the final product [15].

Classification of key requirement analysis and negotiation challenges [13], [14], [20]

1) *Vague requirements.* Vague requirement is the great bugaboo in software requirement and can have several meanings, incomplete or not sufficiently well defined. Consequently, software development can diverged from real features and lead to expensive rework.

2) *Time constraints.* Due to lack of time to deliver the software, requirement engineers quickly analyse the requirements and proceed to development under schedule pressure.

3) *Communication problems.* It is widely recognised that communication problems are a major factor in the delay and failure of software projects. Knowledge acquisition and sharing is very difficult between the stakeholders since misconception and conflicting views are rife.

4) *Skill shortage.* Due to lack of skills, requirement engineers fail to analyse and negotiate conflicting requirements.

5) *Risk assessment.* Risks that can cause project failures are analysed and mitigating strategies are evaluated. Due to lack of time, risks assessment are often skipped or scheduled for later.

6) *Requirement prioritization.* Declaring all requirements to be equally critical deprives the way to respond to new requirements and to changes in project realities such as resources, schedule and quality goals.

7) *Analysis paralysis.* Very often requirement development seems to go on forever when different viewpoints prevail and prevent software development to begin.

C. Requirement Specification

Requirements and specifications are very important components in software development. When requirements are clarified and documented, the corresponding specifications emerge commonly known as the SRS (Software Requirement Specification) document. Many problems in software are traced back to requirements flaws, incomplete implementation of specifications, or wrong assumptions about the requirements. Therefore, it is necessary that the requirements are specified correctly to generate clear and accurate specifications [16].

Classification of key requirement specification challenges [16]

1) *Incorrect requirements.* Change is ongoing during software development and failure to update the requirement document often leads incorrect requirement.

2) *Requirement maintenance.* Requirements inevitably change over time; therefore need to be maintained continuously through techniques such as software configuration management. Failure to do so will result in different versions of requirement documents.

3) *Requirement definition.* Defining requirements is the only process to define the meaning of the software developed. Improper requirement definitions will lead to ambiguity in the software development process.

D. Requirement Validation

Validating requirements means ensuring that (1) the set of requirements is correct, complete, and consistent, (2) a model that satisfies the requirements can be created, and (3) a real-world solution can be built and tested to prove that it satisfies the requirements [17].

Classification of key requirement validation challenges [18], [19], [21]

1) *Incomplete and ambiguous requirements.* Software requirements tend to suffer from uncertainty thus leading to incomplete descriptions of the requirement.

2) *Inconsistent requirements.* Often, requirements engineers fail to write the requirements correctly leading to inconsistent requirements. One apparent reason is the lack of training of requirements engineers.

3) *Unverifiable test results.* A major cause of unverifiable test results is the use of ambiguous terms in the requirements since they are subjective to interpretation.

4) *No good practice for documentation.* There should be some finite cost-effective process by which requirements can be checked either through manual testing or automated tools, thus ensuring the requirements are in accordance to the defined specifications.

5) *Ineffective requirement validation.* Requirements are sometimes validated by the wrong stakeholder on the client side due to unavailability of the required stakeholder. These invalid requirement implementations cause rework in the long run.

III. METHODOLOGY

A. Data Collection Techniques

For the purpose of this research, data on the four phases of requirement engineering were gathered through survey from six software development projects' organizations situated in Mauritius in order to provide a practical view of the challenges identified during the literature review. A simple root-cause analysis of the challenges encountered in the four phases of the requirement engineering reveals key solutions about how these issues can be addressed to bridge the gap between the RE processes and practices.

B. Dynamic Hypothesis H_1: Gap between requirement engineering processes and practices

Research has enlisted many problems and challenges that exist in each of the requirement engineering processes. This paper utilizes survey data from organizations to identify the gap that exists between theory and practice.

IV. RESULTS AND DISCUSSION

A. Requirement Elicitation

According to the survey result in Fig. 1, most of the organizations are encountering requirement elicitation issues including ill-defined system with irrelevant or no complete information, confusion among the stakeholders whereby the user is uncertain of his needs and the analyst lacks domain knowledge. Moreover, continuous evolvement often leads to multiple escalations and complaints about the lack of progress. Another major issue arises when key stakeholders are left out or client involvement is low. All these issues results into consequences that are expensive and difficult to fix, and may ultimately ruin the project.
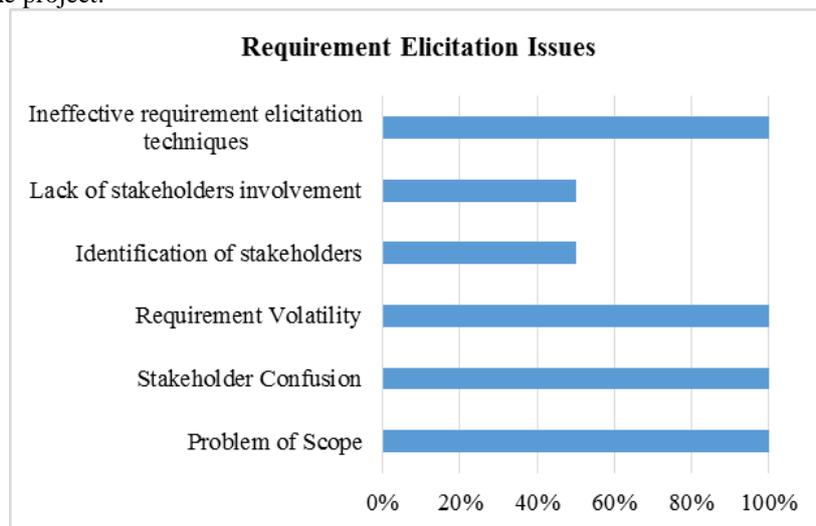

Fig. 1 Survey results for requirement elicitation issues

Proposed solutions of the requirement elicitation issues are described in Table I.

TABLE I PROPOSED SOLUTION FOR REQUIREMENT ELICITATION ISSUES

	Issues	Proposed solution(s)
1	Problem of scope	Having good domain knowledge and proper objectives of the system will reduce the problem of scope.
2	Stakeholder confusion	Making use of natural language during all communications will help to avoid stakeholder confusion. Moreover, coarse grain and fine grain requirement gathering models can be used to provide stakeholders with high and low level views accordingly.
3	Requirement volatility	A requirement management system will be beneficial by tracking all the requirements changes and maintaining traceability.
4	Identification of stakeholders	Ensure the same stakeholders are present from the start till the end of the RE process during each phase where they are required. Moreover, collaboration should be ensured between both parties before conducting any meetings regarding requirements and specifications.

5	Lack of stakeholders involvement	Regular meetings with the agreement and involvement of top management will allow the stakeholders to involve and participate in the gathering. Trying to schedule meetings well in advance will ensure stakeholders are allocated with proper timing for the meetings.
6	Ineffective requirement elicitation	Management should appreciate the importance of proper gathering techniques so that they can be integrated in the project budget. None of the organizations are currently doing architectural gathering, leading to many loopholes in development process, thus a good architectural requirement team will help to decrease the complexity level of the entire system. For instance, by making the stakeholders filling out questionnaires, the architect will be able to trade-offs between requirements.

B. Requirement Analysis and Negotiation

The survey result in Fig. 2 highlighted that requirement engineers have a very tough time to expand and understand the requirements. Very often, there are issues of different concepts of the same requirement between the contracting and sub-contracting organizations and the requirement engineers have to probe deeper to extract the client vision which is very time consuming. Due to deadline pressure, requirement engineers have to analyse the requirements quickly to proceed with the development and consequently there are incomplete or no risk plan in organization. Moreover, analysis and negotiation is often seen as a difficult process due to communication gaps and skills shortage. Sometimes there are gaps in terms of domain knowledge, technical terms or negotiation skills during conflict resolution. Often clients are also reluctant to prioritize the requirements because they fear that developers will automatically restrict the project to the highest priority items and the others will never be implemented.
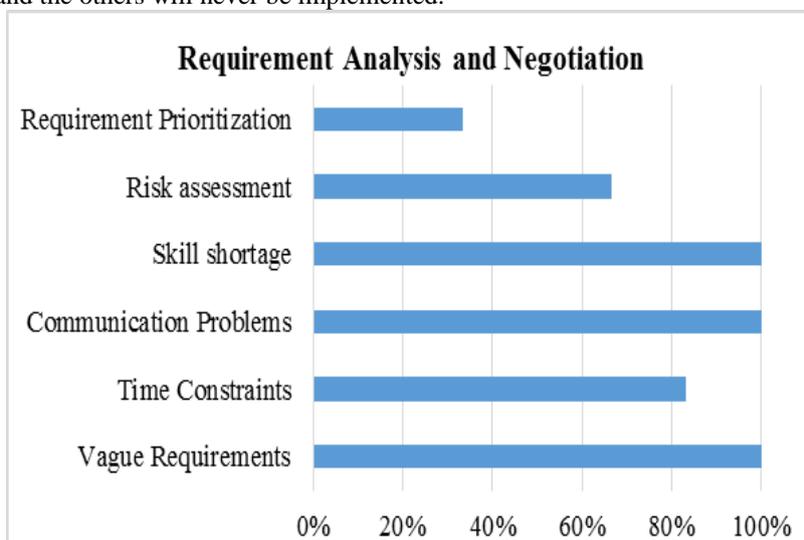

Fig. 2 Survey results for requirement analysis and negotiation issues

Proposed solution of the requirement analysis and negotiation issues are described in Table II.

TABLE II PROPOSED SOLUTION FOR REQUIREMENT ANALYSIS AND NEGOTIATION ISSUES

	Issues	Proposed solution(s)
1	Requirement prioritization	Management should ensure that requirements are aligned with key business requirements and objectives by using a prioritization scale to define the priority categories that clearly promote consistent classification.
2	Risk assessment	Management should ensure that risks plans are made and continuously updated to provide mitigation strategies for identified or new risks in case of changing requirements.
3	Skill shortage	Management should ensure that only skilled, experienced and trained requirement engineers are engaged in requirement gathering processes. Requirement engineer team can be composed of people with diverse perceptions or different positions so that they can be more strategic and dynamic.
4	Communication problems	Management should empower requirement engineer with appropriate trainings on effective communication, technical and negotiation skills to be able to resolve conflicts between multiple stakeholders with different views by critically showing them the likely benefits and importance of their choice.
5	Time constraints	Multiple requirement engineers should have brainstorming sessions in regular interval to ensure a good understanding and prioritisation of the requirements in shorter time frame.

6	Vague requirements	It must be ensured that all requirements gathered are unambiguous by avoiding intrinsically subjective and ambiguous words. A good team with different viewpoints should formally inspect the requirement to ensure they are complete, consistent and verifiable. They can also make use of meta-models to make the requirements more tangible.

C. Requirement Specification

As shown in Fig. 3, all the organizations agree that there is no proper method of requirement definition since stakeholders still make use of emails to share updated requirement. Consequently, some organizations shared that there are outdated versions of the SRS documents which exclude the updates. As a result, there are incorrect requirements since they are not reviewed properly according to standards due to time constraints. These eventually result into tracking problem and incorrect implementation.
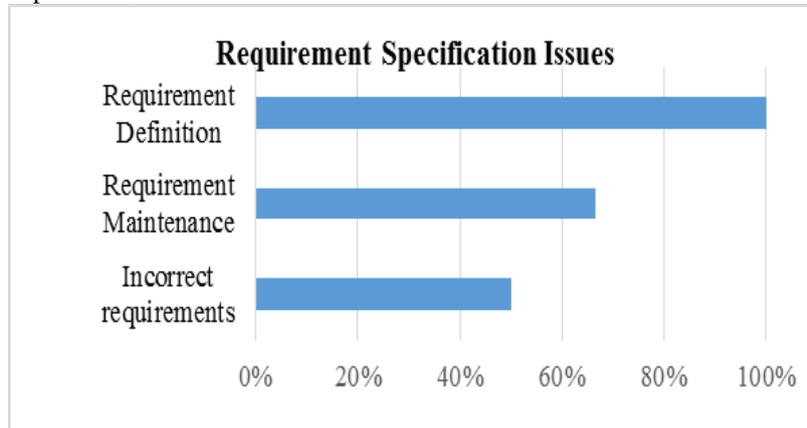

Fig. 3 Survey results for requirement specification issues

Proposed solution of the requirement specification issues are described in Table III.

TABLE III PROPOSED SOLUTION FOR REQUIREMENT SPECIFICATION ISSUES

	Issues	Proposed solution(s)
1	Requirement definition	Proper guidelines and procedures such as the framework of Capability Maturity Model Integration (CMMI) can help to define and maintain requirements. Introducing reviewing of documents in the organizations will help minimise the risk of errors and ambiguity.
2	Requirement maintenance	A configuration management tool will be very helpful to describe the standards and procedures that may be used to control changes in the requirement specification documents. Moreover, a central repository of files can be used to prevent versioning problems and facilitate traceability.
3	Incorrect requirements	By enforcing proper standards to make the developers aware of the importance of having proper documents will make it easier for them to manage.

D. Requirement Validation

The survey results in Fig. 4 pointed out that the organizations still encounter incomplete and ambiguous requirements at the validation stage due to ineffective validation techniques and lack of proper SRS documentation to keep track of the changes occurring in the requirements. As a result, there are still inconsistent requirements and testing of requirements become very complex due to increasing ambiguities.
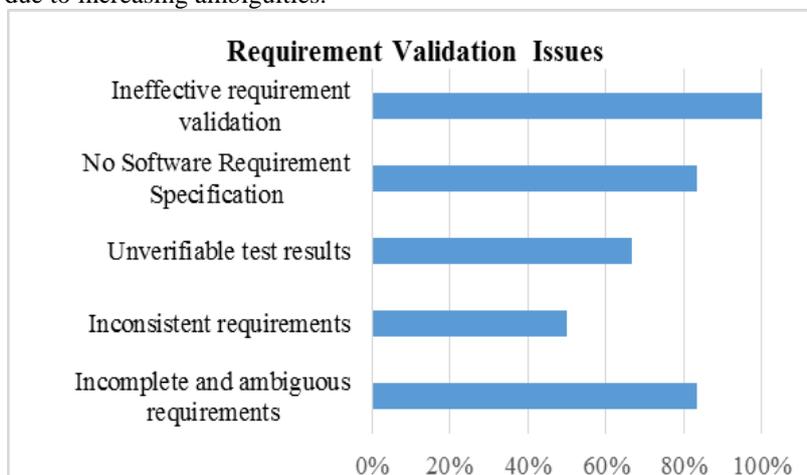

Fig. 4 Survey results for requirement validation issues

Proposed solution of the requirement validation issues are described in Table IV.

TABLE IV PROPOSED SOLUTION FOR REQUIREMENT VALIDATION ISSUES

	Issues	Proposed solution(s)
1	Ineffective requirement validation	Higher management should put more emphasis on this critical issue so as to allocate suitable stakeholders to validate the requirement specification.
2	No good practice for documentation	It is of high importance to establish documentation for effective requirement management to handle volatile requirements and to maintain requirement traceability in order to remove ambiguous and inconsistent requirement.
3	Unverifiable test results	By ensuring that there is some finite cost-effective process by which the requirements can be checked either through manual testing or automated tools thus ensuring that requirements are in accordance to the defined specifications. Moreover, past experiences can help to determine the impact on a particular component.
4	Inconsistent requirements	Having the document reviewed by different people and comparing their feedback will find and avoid inconsistencies that may cause conflicts.
5	Incomplete and ambiguous requirements	Peer reviews, scenarios, and walk-throughs during the requirement elicitation process will help to resolve many incomplete and ambiguous requirements right from the beginning thus easing the validation process.

V. CONCLUSION AND FUTURE WORK

Requirement engineering plays a major role in software development since it is directly proportional to software quality, profitability and client satisfaction. Literature survey highlighted that each process of RE is mandatory to ensure successful software development. However, requirements engineers claims that RE is a very challenging and complex task to gather proper requirements due to numerous issues originating from the four key processes outlined in this research. The purpose of this paper was to illustrate how RE processes are carried out in different organizations to identify the encountered issues in practices. Survey results highlighted a big gap exist between theory and practices. Issues mostly stem from problems related with confusion of project scope, inadequate stakeholders' involvement, communication and negotiation skills, ineffective techniques, time constraints, improper documentation, and lack of requirement management, unprioritized requirements, ambiguous and inconsistent requirements. However, resolving these issues at some stage is necessary for the successful development of the software implementation of requirements. So this paper has proposed numerous plausible solutions to bridge the gap between RE processes in theory and practices so as to ensure highest possible level of software quality, business profitability and client satisfaction. One key principle of this paper was to involve higher management and key stakeholders in most decisions to ensure RE processes are more proficient. As future work, the solutions proposed can be implemented to monitor the change in the RE processes.

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