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A Comparative Study of Requirements Engineering Process Model

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Abstract: In current digital era, software evolution is continuously put into practice by practitioners in order to meet up the changing stakeholder's requirements. It has been investigated that for success of any software system, requirements engineering is very critical phase. This brings an evolution in the scope of the requirements engineering process, along with novel challenges of managing the requirements. Requirements Engineering is considered as a collection of processes that functions on various levels, which incorporate at organizational, product and project level. This paper presents a comparative study of different requirements engineering process models. The objective of the study is to find the vital aspects that contribute to RE process model selection from the viewpoint of practitioners in the business. Several possible future directions for RE process in software engineering are presented, including application specific elicitation techniques, requirements pre-processing, requirements prioritization etc.

Keywords: Requirements Elicitation, Requirements Engineering, Requirement Engineering Process, Requirement Engineering Practice, Research Framework, etc.

I. INTRODUCTION

Software progression is a combination of variety of tools, methods, and practices, which is focused to produce a high-quality software product [1]. Requirements engineering (RE) is a most important phase in the software development that is essential to establish the success or failure of the software product [2]. According to Phillip A. Laplante "Requirements Engineering is a sub discipline of systems engineering and software engineering that is concerned with determining the goals, functions, and constraints of hardware and software systems"[3]. Requirements engineering indulges diverse features but it remains its significance in the development process [2]. Fredrick Brooks pointed out the criticality of RE in his work "The hardest part of building a software system is deciding precisely what to build. No other part of the work so cripples the resulting system if done wrong. No other part is more difficult to rectify later" [4].

Requirements engineering (RE) [5, 6] is the most critical and fundamental phase in software development. The other consequent development phases in software development life cycle depend on requirements engineering phase. Lutz has shown that requirements errors produces 60% of errors in critical systems [7]. Espiti conducted a survey on European companies and found that more than 60% of them considered RE problems as very significant [8]. Proper understanding of each RE process model and techniques are necessary for effective software development. This paper aims at describing different requirements engineering process model, as found in literature and to make out strong point and limitation of each model for future research in the field of RE. The rest of the paper comprises of following sections: Section II comprises Survey of Existing Requirements Engineering Process Models, Section III contains strengths and weaknesses of each one and in Section IV, a comparative table is produced that is based on the critical review. Section IV concludes the paper with future work.

II. REVIEW ON EXISTING REQUIREMENTS ENGINEERING PROCESS MODELS

In our quest to learn about the existing RE process, we explore some of the standard requirements engineering models along with the other models proposed by various researchers for their behavior and working. These models have generally been used in software engineering for the requirement engineering process. The four major Requirements Engineering process models and other models proposed by researchers are described below:

A. Kotonya and Sommerville Linear Requirements Engineering Process Model

Kotonya and Sommerville suggested an abstract linear RE process model, which encompass repetition among activities like requirements elicitation, requirements analysis and negotiation, requirements documentation and requirements validation. This model depicts that the stages in the model overlaps and regularly execute repeatedly [9].

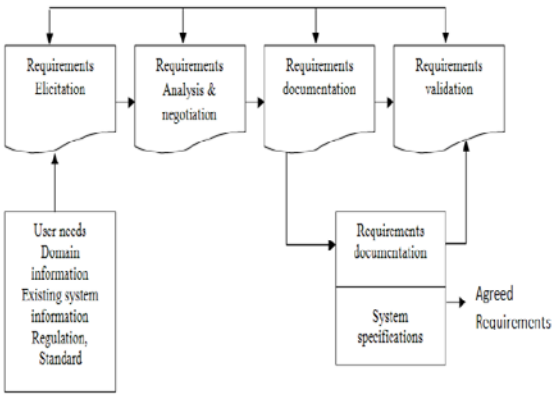

Fig 1: Kotonya and Sommerville Linear Requirements Engineering Process Model

B. Macaulay Linear Requirements Engineering Process Model

Macaulay suggested a pure linear RE process model. It does not support overlapping of activities. The stages of this

model are grouped as concept, problem analysis, feasibility study, analysis & modeling and requirement documentation. Macaulay (1996) described that the requirements engineering process is dependent on situation and customer-supplier relationships. [9]

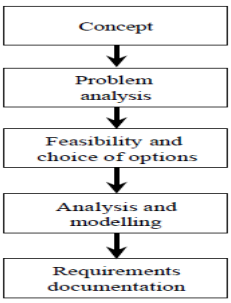

Fig 2: Macaulay Linear Requirements Engineering Process Model

C. Loucopoulos And Karakostas Iterative Requirements Engineering Process Model

Loucopoulos and Karakostas suggested an iterative and cyclic requirements process model. This model exhibits connections between phases of requirements engineering such as gathering (elicitation), requirements specification, validation to the problem domain in iterative manner.[9]

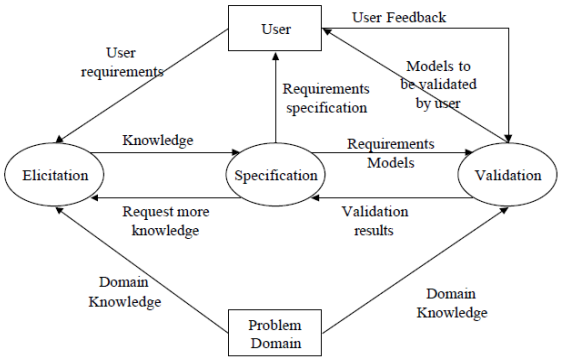

Fig 3: Loucopoulos and Karakostas Iterative Requirements Engineering Process Model

D. Spiral Model Of Requirements Engineering Process

The spiral model for requirements engineering is recommended by Kotonya and Sommerville. The key element of this model is spiral. Each spiral has four major sections as requirements elicitation, requirements analysis & negotiation, requirements documentations and requirements validations. The major objective of the model is to overcome the consequences that affect the quality and cost of the project that occur in various stages of software development. [9]

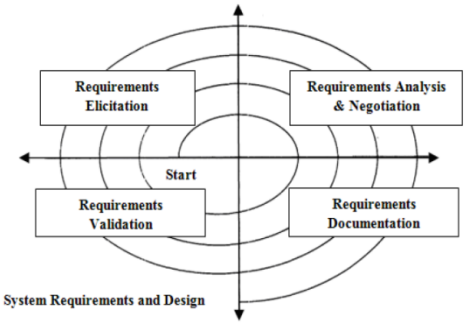

Fig 4: Spiral Requirements Engineering Model

E. Mr. Shams-Ul-Arif, Mr. Qadeem Khan, S. A. K. Gahyyur Tools Cost Benefit Analysis (TCBA) Re Process Model

Tools Cost and Benefit Analysis (TCBA) RE model suggested by Shams-Ul-Arif, Mr. Qadeem Khan, S. A. K. Gahyyur. This model suggested to use survey method for elicitation when the users are in excess and to use interview method if the users are limited to a particular department or office. The model figure out Return On Investment (ROI) prior to the start of the project i.e. computation of costs involving in staff payments, hardware/software, maintenance, recreational, library, networking, employee pensions and health facility. The model also performs risk management and takes customer feedbacks [10].

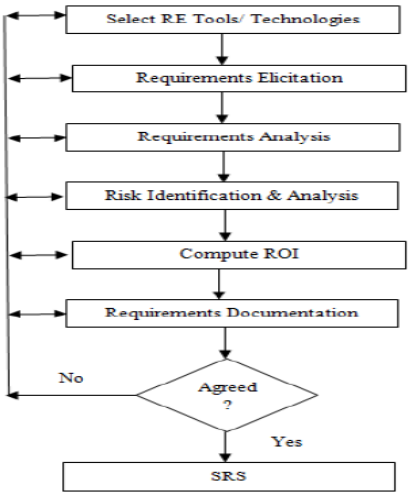

Fig 5: Tools Cost Benefit Analysis (TCBA) RE Process Model

F. Dhirendra Pandey and U. Suman An Effective Requirements Engineering Process Model

The model proposed by Dhirendra Pandey and U. Suman relates requirements engineering process to software development process and introduces all significant and unseen viewpoints of requirements engineering process such as business requirements, customer requirements, user requirements, constraints, security requirements, information requirements, standards etc. for producing quality software products. Apart from including unseen viewpoints this model also incorporates features like requirements management and planning phase to overcome the issue of changing requirements [11].

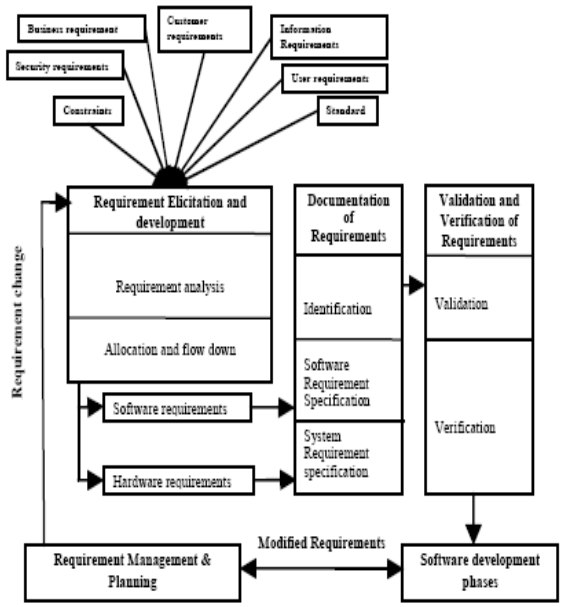

Fig 6: An Effective Requirements Engineering Process Model

G. ***P.B.F. Arts Requirements Development & Management Model In Highly Turbulent Environments***

This model has three major phases such as Intake Phase, Startup Phase and Initiation Phase. The Startup Phase suggested brainstorm technique for requirements elicitation. Initiation Phase prioritize the requirements, performs feedback & validation[12].

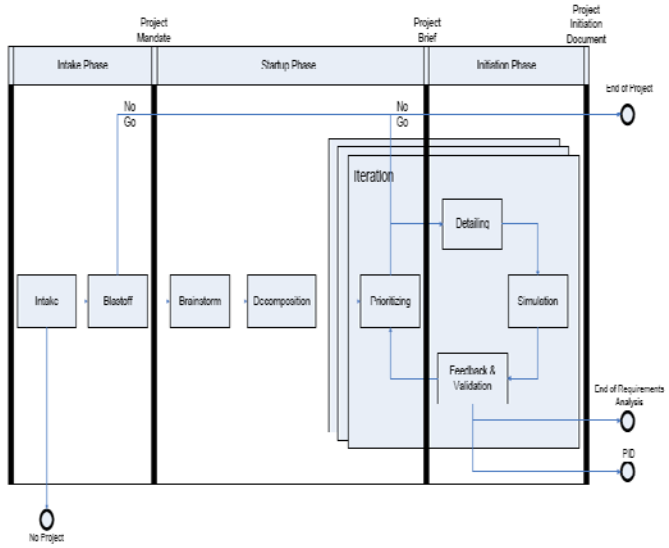

Fig 7: Requirements Development & Management Model In Highly Turbulent Environments

H. ***K S Swarnalatha, G.N Srinivasan, And Pooja S Bhandary Bee Hive Model***

The Bee Hive model increases the swiftness and examines the actual time required for eliciting the requirements from the stakeholders for designing the prototype. The model assures the appropriateness of the well-timed produced code and can be used in evolutionary and conventional prototyping. The phases of the model comprises of Background Research, Requirements Elicitation and Analysis, prototyping, Requirement Verification, Validation and Requirement Specification. Application Domain, Organizational factors, Market, Scale check, Safety and Security are some areas in which background research is carried out [13].

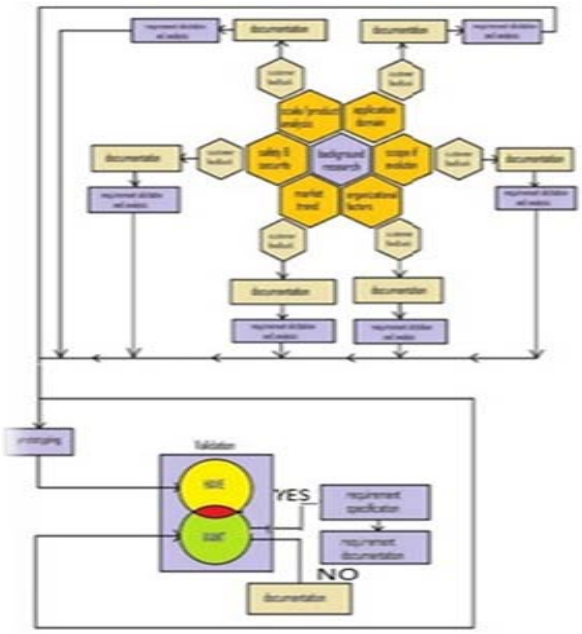

Fig 8: Beehive Model

III. STRENGTHS AND WEAKNESSES

After going through the details of each RE process model, various strengths and weaknesses are recognized, which are specified as follows:

A. ***Kotonya And Sommerville Linear Requirements Engineering Process Model***

Some strengths and weaknesses are identified, which are given as follows:

(a) ***Strength(s):***

- The linear RE process model is a fundamental model that can be used for small projects.
- This model is a basis of other RE process model.

(b) ***Weaknesses:***

- It does not facilitate any kind of requirements validation activity.
- It does not provide support for user feedback.
- It does not support dynamic requirements.
- There is no policy that performs risk management.
- There is no concept of effort estimation on the basis of requirements.
- There are no requirements pre-processing activity.
- There is no criterion for using application specific requirements elicitation technique.

B. ***Macaulay Linear Requirements Engineering Process Model***

Some strengths and weaknesses are identified, which are given as follows:

(a) ***Strength(s):***

- It provide support for analyzing system's feasibility
- It validates the client requirements.
- This model is pure linear in nature and does not involve overlapping of activities.

(b) ***Weaknesses:***

- There is no reverse engineering possible in this model.

- There is no support for risk management activity.
- It does not support for effort estimation.
- There is no concept of requirements preprocessing.
- The model does not support user feedback.
- This model does not provide support for changing requirements.
- There are no criteria for selecting application specific requirements elicitation technique.

C. ***Loucopoulos And Karakostas Iterative Requirements Engineering Process Model***

Some strengths and weaknesses are identified, which are given as follows:

(a) ***Strength(s):***

- Provides support for user feedback.
- Client basically validates the prototype of a system to be developed.

(b) ***Weaknesses:***

- It does not provide a methodology to handle the risks involved in software development.
- It does not support dynamically changing requirements.
- It does not support the concept of effort estimation.
- There is no support for requirements preprocessing.
- It does not involve any criteria for using application specific requirements elicitation technique.

D. ***Spiral Model***

After going through this approach, some strengths and weaknesses are acknowledged, which are given as follows:

(a) ***Strength(s):***

- This model facilitates active user contribution.
- The model incorporates client feedback.
- In this model faults can be found early in software development.
- It supports an effective risk management strategy.
- It grants support for effective reverse engineering process.

(b) ***Weaknesses:***

- It does not compute efforts in requirements phase.
- There is no support for requirements preprocessing.
- It does not support for the concept of requirements prioritization.
- There is no criteria of using application specific elicitation technique

E. ***The Tools Cost Benefit Analysis (TCBA) RE Process Model***

After going through this model, some strengths and weaknesses are identified, which are given as follows:

(a) ***Strength(s):***

- It provides facility for active user involvement.
- It incorporates the feature client feedback.
- Faults can be found in early stage of the software development.
- It grants an effective risk management.
- The major strength of this model is computation of ROI that is resources and budget estimation is done prior to the initiation of the project.

(b) ***Weaknesses:***

- There is no support for requirements preprocessing.
- There is no concept of requirements prioritization.
- Does not support criteria for using application specific requirements elicitation technique.
- Initial fixing of a cost of a product might not be accurate.

F. ***An Effective Requirement Engineering Process Model by Dhirendra Pandey***

Some strengths and weaknesses are identified, which are given as follows:

(a) ***Strength(s):***

- Facilitates for active user involvement.
- It incorporates client feedback.
- This model supports different viewpoints such as business requirements, customer requirements, user requirements, constraints, security requirements, information requirements, standards etc.
- This model incorporates requirements management and planning phase for the software development.
- It supports changing requirements.

(b) ***Weaknesses***:

- There is no concept of effort estimation.
- It does not grant support for requirements preprocessing.
- There is no concept of requirements prioritization.
- Grants no effective risk management.
- There are no criteria for using application specific requirements elicitation technique.

G. ***P.B.F. Arts Requirements Development & Management Model In Highly Turbulent Environments***

After going through this approach, some strengths and weaknesses are identified, which are given as follows:

(a) ***Strength(s):***

- Does not incorporate active user feedback.
- Support changing requirements.
- Support requirements prioritization.

(b) ***Weaknesses:***

- There is no concept of effort estimation.
- There are no requirements preprocessing activity.
- It takes only brainstorming method for elicitation.
- It does not support effective risk management.
- It does not provide support for requirements management.
- Does no support for appropriate requirements documentation.

H. ***K S Swarnalatha, G.N Srinivasan, And Pooja S Bhandary Bee Hive Model***

After going through this approach, some strengths and weaknesses are acknowledged, which are specified as follows:

(a) ***Strengths:***

- It does not combine both parallel and serial model prototyping.
- Feasibility study phase carried out parallel with all other phases.
- It identify and focuses on only to the vital requirements

(b) Weaknesses:

- Large time involved in feasibility study affix complication and required large amount of time for the consequent phases of software development.
- There is no concept of effort estimation.
- There are no requirements preprocessing activity involved in the model.
- There is no concept of requirements prioritization.
- It does not grants effective risk management policy.
- There is no criterion for application specific requirements elicitation technique.

IV. COMPARATIVE STUDY

Various requirements engineering process models are reported in existing literature. Each model have their own characteristics [14]. A comparative study on each model with reference to requirements phase has discussed in earlier section. This section depicts the comparative study in the tabular form. The parameters for comparison are linearity, support for changing requirements, Iterative in nature, user feedback, support for reverse engineering, risk assessment, criteria for application specific elicitation technique, requirements preprocessing, requirements prioritization and effort estimation.

Table 1: Comparison of Requirements Engineering Process Methods

Characteristics	Kotonya and Sommerville Linear RE Process Model	Macaulay Linear RE Process Model	Loucopoulos and Karakostas Iterative RE Process Model	Spiral Model of RE Process Model	Tools Cost Benefit Analysis (TCBA) RE Process Model by Shams-Ul-Arif, Mr. Qadeem Khan, S. A. K. Gahyyur	An Effective Requirement Engineering Process Model for Software Development and Requirements Management By Dhirendra Pandey	Bee Hive Model by K S Swarnalatha, G.N Srinivasan, & Pooja S Bhandary	P.B.F Arts Requirements Development & Management Model In Highly Turbulent Environments
Linearity	√	√	×	×	×	×	×	×
Support for Changing Requirements	×	×	×	√	√	√	√	√
Iterative in Nature	×	×	√	√	√	√	√	√
User feedback	×	×	√	√	×	√	×	√
Support for Reverse Engineering	×	×	×	√	×	×	×	×
Risk Assessment	×	×	×	√	√	×	×	×
Criteria for application specific requirements elicitation technique	×	×	×	×	×	×	×	×
Requirements Pre processing	×	×	×	×	×	×	×	×
Requirements Prioritization	×	×	×	×	×	×	×	√
Effort Estimation	×	×	×	×	×	×	×	×

V. FUTURE RESEARCH DIRECTIONS

Based on this critical review, strengths, and weaknesses of existing Requirements Engineering process models, we have drawn some future research directions, which are given as follows:

- In Kotonya and Sommerville Linear RE Process Model, further research may be done to incorporate requirements validation activity along with support with user feedback to ensure the accuracy, comprehensiveness and uniformity of specification.
- In Macaulay Linear Requirements Engineering Process Model, further research may be undertaken for inclusion of reverse engineering, risk management strategy. This model may also involve concept of effort estimation and user feedback.
- In Loucopoulos and Karakostas Iterative Requirements Engineering Process Model**,** future research may be done by developing requirements preprocessing strategy.
- In Spiral Model, future research may be done by incorporation of requirements prioritization strategy and application specific requirements elicitation technique.
- In Shams-Ul-Arif, Mr. Qadeem Khan, S. A. K. Gahyyur Tools Cost Benefit Analysis (TCBA) RE Process Model, further research may be done by incorporating the concept of requirements preprocessing and requirements prioritization.
- In Dhirendra Pandey and U. Suman Effective Requirements Engineering Process Model, future research may be done by including the concept of effort estimation, risk management and requirements prioritization.
- In P.B.F. Arts Requirements Development & Management Model In Highly Turbulent Environments, future research may be done by supporting requirements preprocessing and effort estimation and requirements management.
- In K S Swarnalatha, G.N Srinivasan, And Pooja S Bhandary Bee Hive Model, further research may be done by including the concept of requirements prioritization and effective risk management activity.

VI. CONCLUSION

In this paper strengths and weaknesses of requirements engineering process model is described. Apart from that a comparative study of the existing requirements engineering models, future research directions is also presented in the paper. Researchers have made considerable advancement in the area of requirements engineering but still development is needed. Presented paper helps the researchers/academia/IT personnel for decision making and further enhancement in the field of requirements engineering process model. We presented a number of research areas, based on the existing literature in which further work is required such as requirements preprocessing, risk management, requirements prioritization, application specific elicitation etc. The incorporation of above mentioned techniques in requirements engineering process model raise the performance, time frame, cost and quality of software development.

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