SYNOPSIS

A STUDY OF FACTORS AND PROPOSAL OF NEW FRAMEWORK FOR REQUIREMENTS PRIORITIZATION FOR SUCCESSIVE RELEASES OF APPLICATION SOFTWARE PRODUCTS

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by

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ABSTRACT

Software Products development typically goes through multiple cycles of requirements analysis, prioritization, design, development, testing and augmenting existing products in order to meet the increasing customer needs, expanding customer base and changing technological trends and improving device platforms.

Each time a software release is planned, the contention of many requirements to be incorporated in the release needs to be resolved. .In this decision making process "Requirements Prioritization" assumes significance. The constraints of available time and resources need to be balanced with realizable Business Value in long term and short term. While a number of methodologies are proposed by Researchers, practical application of these methods for requirements prioritization is hindered as they do not indicate to easy, simple methods that are scalable, flexible and facilitate release planning.

This research focuses on identifying factors that impact requirements prioritization for the software products/applications' building and continuing to meet customers' needs. A study has been carried out with a questionnaire designed based on industry experience to gather information on practices related to "Requirements Prioritization" in software development in different organizations. Based on the Information gathered, Qualitative analysis has been carried out grouping the parameters to reflect relevant areas in product development and identify important factors for requirements prioritization. The goal of the present research effort is to evolve effective, simple and scalable Framework for Requirements Prioritization for software products development undergoing continuous changes and releases.

The thesis provides improved understanding of requirements prioritization in the context of off-the-shelf products and custom made products, based on qualitative analysis of the factors effecting prioritization of requirements. The data is grouped in to 3 datasets – large, medium, small - based on the size of the organization and comparison across the three data sets further enhanced the understanding of various factors' impact on requirements prioritization under varying nature of software developed. A case study is conducted to analyze factors associated with requirements impacting releases.

A new framework, named ABC Framework has been designed taking in to account parameters of relevance in requirements prioritization to enable multi level decision making. The design enables grouping requirements into 3 classes across 5 levels to reflect the practical development process and parameters. For enabling ease of usage, three innovative methods have been suggested to apply the framework in practice. First method represents the framework in the form of sets and requirements association in the sets. Second one has a unique number representation scheme to allow visual interpretation of the various factors' influence on the requirements

prioritization. The third one enables simple use of Excel work sheets to capture classification of requirements based on parameters of importance. Comparison of the ABC framework with four significant Requirements Prioritization methods has been carried out and relative advantages of the proposed framework have been presented.

1. Objectives of the Research

The research presented in this thesis identifies parameters of influence on requirements prioritization and proposes a new and innovative framework for requirements prioritization for Software products development. The framework encompasses parameters considered in industry and adopts classification into three classes across 5 layers of relevance for product development. Two new schemes of representation and visualization of prioritization based on different parameters have been arrived at as part of the research.

Many of the Software Organizations generally use simple methods such as ranking, priority grouping, which do not provide systematic, flexible, scalable methodology for Requirements prioritization in software development in practice. Uncertainties, changes in scope of requirements, multiple parameters to be considered lead to ad hoc handling of requirements prioritization. Systematic methods proposed in research are found to be complex for practice usage and have not been widely used in practice.

In order to address this gap between research and practice, and to address the gap of availability of systematic, simple and easy methods taking into consideration multiple parameters, the following Objectives have been chosen for the research.

Objective 1: To study the factors that influence requirements prioritization and elicit information on order of preference of using these factors.

Objective 2: To compare and analyze data for large. Medium and small software organizations.

Objective 3: To propose a new framework – to enable simple and effective methodology for Requirements Prioritization for successive releases.

Objective 4: To Formulate Mathematical models for practical usage of ABC Framework.

Objective 5: To Compare the proposed framework with four significant Requirements Prioritization methods.

2. Introduction

Software products development starts with identifying specific needs of customers, and cycles through analyzing the extent of each need, designing how these needs can be met in the product, developing some or all of the needs as feasible based on the available resources in terms of time, knowledgeable teams and capital. Various

activities, such as requirements analysis, product features design, development and testing and release to customers are planned either sequentially or in parallel in iterations based on the process methodology followed – water fall, iterative, agile, etc. Fig.1 depicts general software development process.

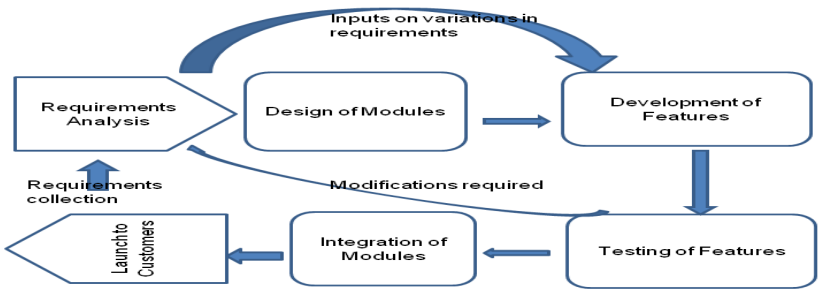

Figure 1. Software Development Process

The products mature in terms of stability and reliability as they are used by different customers for different applications in different environments. At the same time products under go modifications to meet further requirements of existing customers and new customers. Products also undergo changes to incorporate the benefits of advanced technologies. Providing the customers with enhanced products, on a continuous basis, is made possible by successive releases of products at varied intervals, as depicted in Figure 2. Typically successive releases are planned once or twice a year.

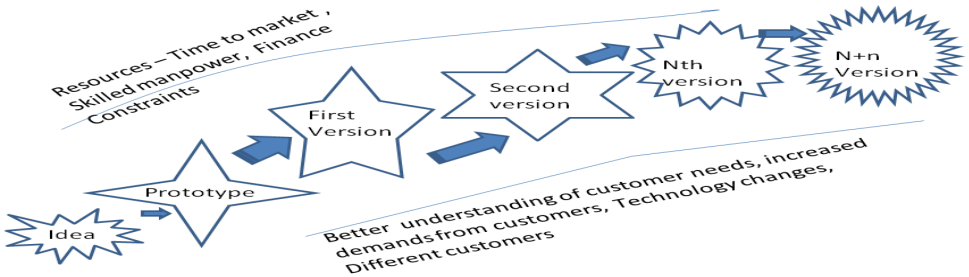

Figure 2. Software successive releases

Software development activity needs the teams to put together the requirements, analyze, and prioritize in order to develop tangible product within reasonable time with available resources. If unlimited time is available and unlimited resources are available, there would be no requirement for requirements prioritization, which is not the case in practice. Not only the limited time to develop or the limited resources, Business Value needs to be considered for the requirements in order to maximize the

Return On Investment (ROI) on software development. The requirements take finite time of resources to get developed; hence development time needs to be considered. If the development is for successive version of the product/solution, the analysis needs to consider how the requirements are going to impact existing customers and also existing software components.

3. Relevance of the Topic and Research Focus

Requirements prioritization is the most significant part of software development to enable right products/solutions development in right time with optimal resources. Literature study points to simple to complex methods for requirements prioritization being researched and gap between research and practice due to difficulties in implementing the research methods.

Literature survey indicated to many methods being discussed. Simple methods are used in practice, though insufficient. Many complex methods are discussed in literature, but rarely applied in practice. Evaluation of different methods, though available to some extent in literature, is often not on a standardized base set of requirements and not applicable to requirements in general. There is also lack of appropriate bench marking related to factors influencing the prioritization and the relative order of influence of the factors based on nature of product domains. The methods target one time prioritization with accurate information not being available. Scaling is an issue with these methods, in that the number of calculations and comparisons becomes cumbersome. Re-planning under changes requires rework.

Requirements prioritization remains an area handled in ad hoc manner and methods being used for approximate prioritization serving limited purpose. The methods used do not consider all variables in a systematic way. While a combined importance of requirements is normally used to encompass all parameters implicitly, for prioritization most of the times, cost –value ratio or risk weighted cost-value ratio is also used sometimes. These methods do not provide flexibility in prioritization under changes or retain the information as to what are the considerations in prioritization process. Some of the methods can be applied recursively taking each parameter in to consideration, successively. Some methods can be applied hierarchically to prioritize requirements at different detailing levels.

There is a general agreement on the parameters of relevance for requirements prioritization, though there does not seem to be a detailed study on these parameters and the order in which their importance is relevant in literature. While there has been recent work combining two or three simple methods or suggesting fuzzy logic and genetic algorithms for requirements prioritization to address uncertainty in prioritization, there have not been efforts to study and analyze what happens in practice and what parameters matter and in what order. In addition, methods that are simple, flexible yet comprehensive taking in to account the parameters of relevance are yet to emerge for requirements prioritization.

Problem Statement/ Research Focus

A simple and standardized framework that can be modified for different domains and used for comparison for the purpose of Requirements Prioritization in practice for successive releases of Software Products has not yet materialized to bridge the gap between research and practice in software industry. The proposed research attempts to bridge this gap, by proposing a suitable framework from based on the study of factors that influence prioritization of requirements.

The research focuses on study and understanding of factors influencing requirements prioritization and proposing a Framework, that leads to simple and effective requirements prioritization for successive releases of software products and offers scalability, flexibility, visibility and traceability across the development life cycle leading to improved quality and release planning.

4. Methods in Literature Survey and Research Gaps

Significant Research and empirical studies have taken place in the area of requirements prioritization and release planning. Methods have evolved for prioritizing requirements based on different parameters - Value and Cost being prominent among them. Some of the long standing methods are - Analytical Hierarchy Process- AHP, originally applied for decision making in projects selection, Cost-Value approach by Karlsson, Wiegers method of weighted ratio of (value + penalty) to (cost + risk) and Priority Groups method. Davis advises simplifying the process and advises Triage at successive levels, taking into account market realities. Industry specific studies for products meeting certain specific base parameters seem to have been very few. This makes the conclusions and comparisons difficult to be applicable or reliable.

A total of 90 articles have been studies to understand the nature of research work carried out on requirements prioritization and related areas of software product development. The research works include 70 Research papers; 13 Doctoral Theses, 2 post grad papers, 5 workshop/book chapters of the period - 1996 -2015. Since prioritization is a decision making process, study of decision making literature has formed part of this exploration. Summary of findings from the literature survey is listed below.

1. There is general agreement on the parameters that influence requirements prioritization for releases in the literature. Cost of Development and Business Value of the feature in their overall sense are used for prioritization across literature except in two methods.
2. Most of the literature covered four methods for Requirements prioritization – AHP, Weigers, Priority Grouping and Cost-Value Method - and combinations of them.

3. Some of the literature has studies on AHP, Cost-Value, Priority grouping, with theoretical comparisons.
4. Saaty's multi level decision making framework , which is applicable to many domains with problem domain specific parameters defined has often formed base for Cost-Value and layered prioritization concept.
5. Methods like Wiegers take into account the risk of not implementing a feature and impacts.
6. Two Tools evolved of the research on requirements prioritization – one being for decision making by Saaty based on AHP and the other being for triaging.
7. Only Four papers have practical studies across projects. Other literature is with sample university projects and not with industry projects. Of the industry related projects, the projects varied widely across domains, nature of development.
8. It is observed form the study that when the methods were compared, the methods did not have a common base line of projects, wherein comparisons could be valid. The nature of projects, level of requirements abstraction varied widely for deducing practical use of comparisons.
9. The methods proposed are complex and do not represent the software development life cycle needs closely. They become tedious to apply and inaccurate to use. They also depend on data being accurate for appropriate prioritization. Recent methods proposed, tried taking cues from other domains, such as fuzzy logic, genetic algorithms, making the process of applying these methods complex.
10. A school of research by Alan Davis encourages simple methods like triaging at multiple levels based on different parameters relevant – such as Cost, Value, Impacts, Time to Market and Resource availability.
11. It is observed that the methods surveyed do not offer the flexibility of re-planning, re-prioritizing in a simple way.
12. Impacts of changes in prioritization and how planning changes under prioritization changes is discussed in one paper. Visualization of planning changes due to prioritization changes during the development cycle is an area under-addressed.

5. Research Methodology

The Objectives set for research are attempted to be achieved through steps as depicted in Figure 3.

Due to the confidentiality and IPR issues , involved in obtaining relevant information on the topic, it is difficult to collect data from a statistically significant sample of participants. In view of this challenge, data was collected from a broad cross section of professionals, that are actively involved in Requirements Prioritization decisions, using a structured questionnaire, primarily through one-to-one interactions. It was followed by discussions with experienced professionals.

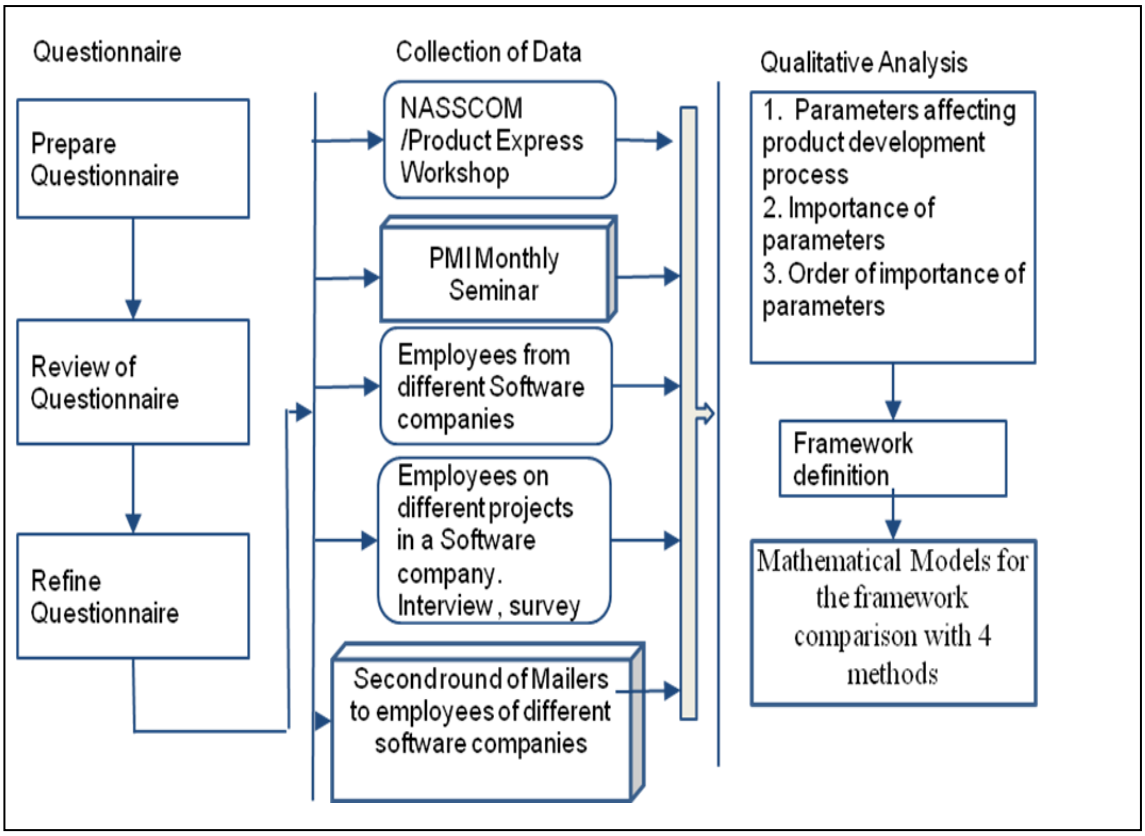

Figure 3. Research Methodology

Questionnaire

In order to understand the current practices related to software product development, processes followed at different organizations developing products and solutions for different domains and platforms, a questionnaire is designed. Study has been conducted with relevant organizations and practitioners. The questionnaire is visualized to be exhaustive and comprehensive to address different stages of product development. The questionnaire has been prepared based on the scholar's own experience with multiple products' development companies. A review of the questionnaire has been taken up with the industry experts in product development. Keeping in mind the data collection ethics, name and organization were not requested in the questionnaire initially. Both these details are requested for subsequent study based on the feedback received.

The Questionnaire is structured around parameters like products domain, maturity of the products, development process variations and requirements handling modes. The objective of the study is to understand the factors influencing prioritization of requirements for software development. The study attempted to understand practices related to requirements' prioritization among software development organizations and association of requirements prioritization' effects on software deliveries and resources. The study is conducted to understand the effectiveness of the current

processes and to identify requirements prioritization needs for enabling planned deliverables with reduced uncertainties.

6. Data Collection and Analysis

NASSCOM's 2015' Report on Software products states there are more than 4000 product firms in India, with 300 to 400 being both product and services firms. There are 300+ MNCs active in domestic market according to NASSCOM. India's software product segment is dominated by integrated firms and MNCs dominate domestic market in revenue terms. The expertise of software products development, be it off-the –shelf or customized solutions, lies largely with the MNCs and large organizations. Gathering this knowledge from various firms in the important area of requirements prioritization in products development is attempted in this research. Due to the proprietary nature of work carried out in product development, coupled with the associated Intellectual Property Rights (IPR) Issues, information gathering posed challenges. Responses could be received from 106 participants in about 61 organizations over a period of 2 years with difficulty.

Importance of various factors on requirements' prioritization in software product releases is studied through Qualitative analysis of the responses. Data is grouped by Organization/Project Size for understanding impact of size of organization on prioritization. Variations in different influencing parameters in conjunction with size is brought out through the analysis. Influence of nature of software due to varying domains, software maturity, and complexity of software on requirements prioritization is analyzed. Nature of software information is elicited from Section I of the questionnaire. The processes followed, difficulties faced with current processes are analyzed from section II responses. Prioritization methods used, parameters considered is taken from the responses of section III. Data is analyzed to bring out the factors of relevance for prioritization of requirements and also the order of factors of relevance. Comparison of responses across the data sets- large, medium, small gave view of consistency and variations in responses across these data sets, which enabled strengthening the analysis.

Of the 106 participants from 61 organizations, 51 (48%) are from Large (>200 resources) organizations, 40 (38%) are from Medium (25-200 resources) organizations and 15 (14%) are from small organizations(<25 resources). Large organizations handled multiple product lines and many products, where as medium organizations have considerable product lines and products, while small organizations handled single product lines. 61% of the participants handled multiple product lines. Complexity of the products appeared similar across the organizations, with 48% working on 3 tier, 38% working on 2 tier and the remaining on single tier products. Large and Medium organizations worked on global products, while small organizations worked on single country products. Large organizations are involved in Engineering and system software, while Medium and small catered for Ecommerce, web/mobile Software as well. The diversity of the domains is indicated by 21% of

participants working on web/mobile technologies, 25% on ecommerce and 54% working on engineering software. Release cycle of the products tended to be longer – year, year+ in large organizations and medium and small have shorter release cycles – half year or less. Large organizations handled mature products compared to medium and small. About 20% of participants worked on highly mature products of above 10 years span, 61% worked on products of 2 to 10 years life span. 45% of the participants participated in products planning across. Participants participated in activities across Software development - analysis, estimation, prioritization and also implementation.

Analysis on the process and requirements management lead to the following conclusions - The processes followed across the organizations are Waterfall, Iterative and Agile, Agile being the predominant process. Large companies followed a mix of processes, where as small companies preference has been with Agile.

It is evident from the study that all players - Marketing team: for customer needs and business value, Executive Management: for strategic direction, Development Team: for efforts estimation and technology impacts, Maintenance team: for customer impacts and customer change requests are involved in prioritization of requirements for the releases. Product teams carry out the evaluation of requirements. 26% of responses indicate to Ranking by value proposition for prioritization. Ranking by value, resource availability, time availability is indicated by 52% of the responses. 71% of the participants consider priority grouping is sufficient for prioritization. 60% consider ranking and numerical assignment sufficient and 56% consider Cost-Value ratio sufficient for prioritization.

Relative importance – how much more – is considered important by 82% participants, while the methods that provide this information – AHP and Cost-Value based on AHP are not widely used in practice.

Responses to the usage of 5 parameters relevant in requirements prioritization – Business Value(BV), Availability of Resources(AR), Time to Market(TM), Difficulty of Implementation(DI), and Impacts on Customers/Core(IC) – indicated to 61% using at least 3 parameters for prioritization. BV is considered by 70+ participants of the 106 responses. In addition to what parameters are used for prioritization, order of usage of parameters is analyzed. BV,TM,IC,AR,DI comes out to be the preferred order with 33% responses and BV,DI,AR,TM,IC is preferred by 23%. About 66% responses indicated usage of weighted parameters for prioritization.

The study and analysis indicate the need to focus on relevant factors influencing requirements prioritization for planning releases. The methods generally used - relative ranking and grouping into - must have, good to have, need not have and cost-value prioritize based on overall importance or aggregated cost and value. Inappropriate requirements prioritization often resulted in teams working under pressure, extended release dates, dropped features.

The purpose of getting a set of requirements implemented for the next release (time bound) is to maximize the business value of the release for the most valued customers. A strict ordering of requirements may not be the need. Need is more for a near optimal sets of requirements. The study brings out the factors – Business Value(BV), Availability of Resources(AR), Time to Market(TM), Difficulty of Implementation(DI) and Impact on existing Customers(IC) relevant to requirements prioritization. The preference for order of considering these factors for prioritization enables a multistage decision framework for prioritization. This analysis has paved way for defining 5-stage framework encompassing the parameters and weights to different parameters.

Parameters of Relevance across 3 datasets grouped based on size

The study over a period of 2 years offered an opportunity to analyze different factors' variation and consistency across three data sets grouped based on the size of the organization. The data presented an interesting opportunity with participants from small(14%), medium(~38%) and large companies(~48%) enabling the grouping of the data. Size of the organization, and in turn, nature of Software development, influences how requirements prioritization is taken up in the organizations. Different aspects – domains, maturity of the products, release cycles, spread of usage, complexity of the software influence how requirements prioritization is handled. The study highlighted the association of the size of the organization to these aspects in section I. While customer needs influence prioritization with small and medium organizations, large organizations tend to deal prioritization systematically with business analysis, backlog planning and stakeholder discussions, Requirement clarity appears to weigh more as a problem area for medium and small organizations. Prioritization methods perceived sufficient preferred across are –Numerical Assignment, Relative ranking, Priority grouping and cost-value. Inappropriate requirement prioritization often resulted in teams working under pressure, extended release dates, dropped features. Large organizations circumvented problems by further analysis, estimation and extension of release dates, while small and medium organizations either managed the clients through discussions or put in additional work.

The study brings out the use of the factors – Business Value (BV), Availability of Resources (AR), Time to Market(TM), Difficulty of Implementation (DI) and Impact on existing Customers(IC) with small, medium, and large organizations for requirements prioritization. While not all five parameters are utilized by all, at least 3 of them are used by more than 70% across. BV being the most and first used factor for prioritization, large organizations focused on TM as second factor, while small organizations considered DI as second factor for prioritization mostly. BV-TM-IC-AR-DI emerged as the preferred order of considering these factors for prioritization for large organizations, whereas small organizations preferred order is BV-DI-TM-AR-IC. Use of weights with factors appears to be the requirement for prioritizing the requirements across the datasets. The study and analysis indicate the need for multistage framework for requirements prioritization. A new multistage decision

framework is defined based on the understanding of factors, order preference from the study.

7. Proposed Framework

Based on the study, a Requirements Prioritization Framework has been proposed, reflecting the practical aspects of the software development. As classification of requirements is effected into three classes – A, B, C based on the relative importance of the impacting factors at successive levels of the framework, the framework is named ABC Framework. The framework takes into account different parameters, elicited from the study – Business Value, Time to Market, Difficulty of Implementation, Availability of Resources and Impact on Customers/Core. The Framework considers the course of software development and links the prioritization to development process, release planning, change management, quality management.

7.1 The Framework

ABC Framework is defined as 5 sets based on most used parameters in the sequence of priority determination. Each set is defined by three classes defined by % value of the respective set parameters. Requirements are grouped in to the classes in the sets in the process of prioritization. The % bands may vary from industry to industry and organization to organization to some extent. Prioritization sets S1 to S5 and classes/bins A, B, C within each set are described in Figure 4 in the next page.

- **S1.** Business Value(BV) in conjunction with Customer Base (CB) – with classes -
  - A:20% of CB with 70% BV
  - B:30% of CB with 25% BV
  - C:50% of CB with 5% BV

- **S2.** Requirements Applicability with respect to product – with classes
  - A:70% UW, 30% BI, 0% CP
  - B:50% UW, 40% BI, 10% CP
  - C:30% UW, 50% BI, 20% CP

Where

- UW: User Interface/Workflow Specific/Specific Customer Set ,
- BI : Business Logic/particular Industry vertical,
- CP: Core/data model level /across the portfolios.

- **S3.** Implementation Cost–
  - A: 70% MI,25% NI,5% IR
  - B: 50% MI,40% NI,10% IR
  - C: 30% MI, 50% NI, 20%IR

Where

- MI: Marginal Implementation, NI: New Implementation, IR: Impact Recovery

- **S4.** Time Requirement –
  - A: 10% L,20% M, 70% S
  - B: 15% L, 25%M,60%S
  - C: 20% L, 30% M, 50% S

Where

L: 8 to 16 person weeks , M:4 to 8 person weeks, S: 2 to 4 person weeks

- **S5.** Resource Requirement –
  - A:10%RC,20%RI,70%RT
  - B:15%RC,25%RI,60%RT
  - C:20%RC,30%RI,50%RT

Where

- RC: Resources - Core aware (6y) - domain/architecture/design/technology
- RI: Resources - Industry aware (4y) – domain/design/technology
- RT: Resources – Technology aware (2y) – Technology/Skill

Figure 4. Prioritization Sets and Classes

7.2 Benefits of the ABC Framework

Following are the broad benefits of the proposed framework –

a. Link to Development process

In addition to arriving at the prioritized requirements set, the suggested process of requirements classification can be extended to determine the development process most suitable for implementation of the requirements as described below .

- Agile/Iterative/Waterfall –no one process may be suitable for all requirements.
- Follow Agile for requirements emerging through A across Sets

- Follow Iterative for requirements emerging through AB combinations
- Follow Water fall for requirements emerging through ABC combinations.

b. Effective Quality Planning

- Requirements classification in to 243 bins enables test planning appropriately.
- Level and importance of testing a requirement can become a function of the bins.
- Nature of testing can be determined based on the bins.
- A priori information available to test teams

c. Flexible Release Planning

- Effects of Adding/removing requirements during the release cycle will be clearly visible.
- Uncertainties can be accommodated in re-planning easily.
- With the 243 bins available modular release planning becomes feasible.

8. Mathematical Models for ABC Framework

Three innovative methods for representing the priorities have been proposed for the framework defined. The framework has 5 sets – ranging from S1 to S5 with S1 being the first level and determining the Business Value for the requirement. S2 looks at the existing capabilities in terms of components, products and effort required broadly for the new requirement. S3 goes deeper with effort understanding along with impact insights. S4 attempts to get at time requirements for the job at hand for the requirement, whereas S5 assesses the capabilities in terms of resources. The first method uses Excel tables for classifying the requirements in to classes at successive levels. The other two methods are described here.

8.1 Interpretation through Sets for the ABC framework

The requirements are assigned into classes and distinct Priority is arrived at by multiplying the class weights across the sets. Assuming weights of 3/3, 2/3, 1/3 for classes A, B, C respectively, macro level priority - Pm is arrived at for each requirement by multiplying the class weights across sets. The priority can vary from AAAAA resulting in 1 to CCCCC resulting in 0.001372, providing a range of priorities for each of the requirements. The priorities need not necessarily be unique. Same priority requirements can be grouped together for simultaneous development.

8.2 Unique numbering scheme for the framework

While a single number may be useful to look at relatively at the requirements, the intelligence of classification into classes is lost from visibility. In order to retain the class information and yet arrive at a weighted priority scheme, the following number sequence is proposed.

Assigning a five digit sequence with each set holding the positional value from S1 to S5 in that order, the sequence will be a number, where each of S1, S2, S3, S4, S5 can have values - 0 or 1 or 2 based on which class of A, B, C, a requirement falls into. Each position having three values – 0, 1, 2 and with 5 positions of value, the number of sequences equals to 35, that is 243 sequences.

All the 243 values of sequence will range from 00000 to 22222, with each value in each position representing the class and set the requirement belongs to. This enables immediate interpretation of the priority with respect the requirements associated Business value, resources availability, time requirements, cost implications.

9. Comparison of ABC Framework with other Methods

ABC Framework is compared for ease of use, scalability, number of operations, flexibility, with 4 methods – AHP, Cost-Value, Weigers Method and priority grouping - often referred in literature.

9.1 Summary of comparison

Summarizing the comparative analysis , ABC Framework offers the ease of Priority grouping method adopts the hierarchical decision making concept of AHP, takes into account different aspects of practical relevance in software development space, which, in effect, are common with cost-value-penalty-risk. Any dynamic changes in priorities of requirements can be easily integrated, visualized and interpreted in ABC framework. The impacts on release plans and coming up with new release plans is similarly simple with ABC framework. Comparison of various aspects of the prioritization methods is presented in Table 1.

Table 1. Comparison of Methods

Method	AHP	Cost-Value	Weiger	Priority grouping	ABC Framework
Methodology	Pair-wise comparison	Pair-wise comparison	Independent assessment by estimation	Independent assessment	Independent assessment
Criteria	Importance . Can have multiple criteria	Cost, Value	Value, Penalty, Cost, Risk	Importance. Can have multiple criteria	Business Value, Nature of requirement, Implementation costs, Development time , Resources
Scale	1,3,5,7,9 2,4,6,8 reciprocals of above	Same as AHP	1(low) to 9(high)	Grouping into 3 or 4 groups	Classifying into three classes in each set

Levels	As needed for other criteria	As needed for granularity	As needed for granularity	As needed for granularity	5
Number of decisions for n requirements	n(n-1)/2 for each criteria/ level	n(n-1) = 2 * n(n-1)/2	4n for single level	n for single level	5n
Priority representation	Eigen values of comparison matrix	Eigen values	Value% / (cost% *weight + risk% *weight)	Group membership/ranking	Class membership in each set
Visualization of influencing factors in final priority	Relative priority	Cost-value diagram	Relative priority	Ranking in group.	Class/set association sequence
Changes incorporation	Rework the process	Rework the process	Rework the process	Can be added/removed as needed	Can be added/removed as needed
Visualization of change impacts	-	-	-	-	Relative Class sequence, macro priority
Release plan determination, changes in release plan visualization	based on relative priority	Based on cost-value diagram/correlation	Based on relative priority	Based on ranking	Based on release theme relevant class/set sequences

In addition, it provides a unique representation for prioritization of the requirements. The framework enables understanding and interpreting prioritization in a visual and instant way. The Framework and priority representation enables simple and effective methodology for Requirements Prioritization for successive releases under dynamic changes and lead to better understanding and planning of releases. It helps in prioritization of requirements and planning releases, streamlining the project deliveries to client's satisfaction without overworking the teams or missing time to market deadlines, providing dynamic prioritization throughout the process of software development. Advantages of ABC Framework over other methods are listed below.

1. Relates closely to the Software Development problem space and handles prioritization not as an isolated activity, but as an integrated release planning activity, unlike other methods.
2. Takes into account parameters relevant to software development process.

3. Prioritization is handled at 5 levels, reflecting decision making process of prioritization throughout software development process, with flexibility of using less number of levels optionally.
4. Simple 3 classes decision making process is effectively used to generate 243 priority groups, which is normally sufficient to handle large number of requirements, circumventing the scaling problem of other methods.
5. Considers the uncertain, approximate information on prioritization and does not attempt to attribute preciseness to the priorities. Rather allows final prioritization to emerge easily out of this imprecise information on prioritization.
6. Provides unique numbering scheme - to represent prioritization of parameters considered with visibility.
7. Allows easy re-planning under dynamic changes in prioritization during release cycle and helps view multiple options visually, while other methods need reprioritization a fresh and do not offer visibility into planning of releases.

10. Conclusions

10.1 Conclusions

The research presented in this thesis explored research gaps in requirements prioritization and gathered and analysed parameters influencing requirements prioritization. Further a new and innovative framework is proposed for requirements prioritization for Software products development. Two new methods are developed for applying the framework practically. Applying the framework and its advantages are demonstrated. The framework encompasses parameters considered in industry and adopts classification into three classes across 5 layers of relevance for product development. Two new schemes of representation and visualization of prioritization based on different parameters are arrived at as part of the research.

The research focused on the factors relevant in requirements prioritization for the software products building and continuing to meet customers' needs. Relevant factors are identified through a study conducted with a questionnaire prepared based on industry experience. Qualitative analysis is carried out grouping the parameters to reflect relevant areas in product development. The goals of the research effort in this thesis -to provide effective and simple methods to visualise and prioritize requirements for software products development undergoing continuous changes and releases -.are accomplished by defining the framework and devising innovative mathematical models for using the framework.

The thesis provides improved understanding of requirements prioritization in the context of off-the-shelf products and custom made products, based on qualitative analysis of the factors effecting prioritization of requirements. A case study is conducted to analyse factors associated with requirements impacting releases.

The new framework designed to help in requirements prioritization is based on grouping requirements into 3 classes across 5 levels to reflect the practical development process and parameters. Three different ways are suggested to apply practically the framework. First method represents the framework in the form of sets and requirements association in the sets. Second one has a unique number representation scheme to allow visible interpretation of the various factors influence on the requirements prioritization. The third one enables simple use of excel work sheets to capture classification of requirements based on parameters of importance. Comparison of the framework with four of the generally used requirements prioritization methods brought out the advantages of the proposed framework.

10.2 Meeting Objective of the Research

Objective 1: To study the factors that influence requirements prioritization and elicit information on order of preference of using these factors.

Outcome: Objective 1 has been accomplished through study of parameters as discussed and analyzed in chapters 5, 6, 7 across 61 Organizations with 106 participants. Analysis across 3 data sets provided additional confidence in bringing out different factors influencing requirements prioritization.

Objective 2: To compare and analyze data for large medium and small software organizations...

Data has been grouped according to size of organization – large, medium, small and data is compared for understanding the effect of scale of organization on different factors influencing requirement prioritization. The analysis is presented in Chapter 7 in the thesis.

Objective 3: To define a framework based on the understanding derived from Objective 1 to enable simple and effective methodology for Requirements Prioritization for successive releases and lead to better understanding and planning of releases.

Objective 3 is achieved by proposing a framework – ABC framework – a multi level decision making framework, taking into account parameters of relevance for practical software development with the understanding from the study carried out.

Objective 4: To Formulate Mathematical models for practical usage of ABC Framework.

Two new innovative schemes are presented for representing priorities and application under changes in priorities. Excel sheets based method is suggested for applying the framework, in addition.

Objective 5: To Compare of the ABC framework with four other methods.

ABC Framework proposed in this research is compared with AHP, Cost-Value Method, Wiegers Method, Priority grouping Method on multiple aspects of ease of use, number of calculations, usage under changes, scalability.

10.3 Limitations of the Research work

The research encompassed gathering data from industry on practical aspects of software development and deriving knowledge on practical issues and needs in requirements prioritization. The scope of study currently covered in one group multiple domains, multiple types of development, across regions. The study can further expanded to include domain specific studies, type of development studies and differentiate specific needs.

While a multi level decision making framework specific to software development is developed as part of this research based on the present understanding of the parameters, the framework can be further refined to suit specific domains and can be standardized industry wise. Applying for successive releases and continuous development in industry is required for confirming the advantages of the framework.

10.4 Future Scope for Research

With the framework in place and aided by the understanding of the factors influencing requirements prioritization and the importance of prioritization for release planning under constraints, carrying out case studies at different software organizations through successive releases is planned to be taken up further. The advantages of the defined framework in practice and there by the benefits to the organizations, in terms of smooth and timely, quality and complete deliveries of software, will be studied further to this research. It is also planned to develop a tool for enabling usage of the Framework

11. Thesis Layout

Thesis has 12 chapters starting with Chapter 1 introducing Software Product development area. Off-the shelf software product companies and custom product development companies are discussed in this chapter. Processes followed for product development -Waterfall, Iterative, Agile are elaborated.

Chapter 2 presents the survey of literature and description of some of the prominent methods. Recent trends in research are presented. Chapter3 discusses the objective of the research and presents the research methodology followed for the study and analysis as part of the research. Chapter 4 elaborates on the study methodology, data gathering process and nature of data

Analysis of the study on processes and problem areas is presented in Chapter 5. Chapter 6 explores study on Requirement prioritization methods and factors. Chapter 7 analyses the consistency and variance of the data across 3 datasets grouped based on the size of the organization, from the gathered data.

As a result of the understanding of the current methods and study results, the design of the proposed framework for Requirements prioritization is discussed in Chapter 8. Advantages of the proposed framework for product development are highlighted.

An innovative mathematical modelling of the framework is presented in Chapter 9. Comparison with four methods is provided in chapter 10. The study conclusions and further scope of research are presented in Chapter 11. Papers published/presented in journals/conference proceedings are presented in Chapter 12.