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Selection Criteria for Requirement Prioritization Techniques

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Abstract

Requirement analysis is a critical stage in the software development lifecycle that drives project success. Software results are greatly impacted by elicitation approaches that are aligned with stakeholders' needs, including both functional and non-functional factors. Finding the best approach to requirement prioritizing is difficult even with the wide range of approaches available. Value-based requirements are carefully woven into particular priority criteria by this study, which pioneers an approach that assesses requirement prioritization techniques based on four important elements. The work emphasizes the computation of full scores for different methods, providing definitive graphical representations that enable comparison assessments. This novel method simplifies requirement prioritizing analysis and selection by providing a structured framework for assessing and selecting the best solution in a particular situation. Through the integration of many elements and alignment with stakeholder requirements, this approach provides a systematic framework designed to improve the effectiveness of requirement prioritizing in software development. Its diverse approach tackles the intricacies present in these procedures, ultimately leading to more efficient decision-making in software development projects.

Keywords Factors affecting requirement; Requirement prioritization techniques; Requirement Engineering; Requirement analysis; Software product planning.

INTRODUCTION

In the software development lifecycle, requirement gathering and managing are very important. Requirements can be defined as stakeholder's expectations of a system's end product, functional abilities, or non-functionalities. Requirement Engineering is considered early in the software productdevelopment life cycle. The process of dealing with requirements started in 1960. The requirement elicitation process is the firm basis of software product success. Requirement gathering and analysis will decrease the communication gap between developers and end-users. The requirement designing procedure incorporates a few exercises:feasibility study, requirements collection, sorting, structuring, prioritization, validation, requirement, and management. Researchers have

focused on and explored requirement engineering (RE) for the past few years (Narendhar et al) but there is still a gap between research and practical implementation of RE processes. The trim level management and elicitation of requirements canbe done using many tools and languages, such as UML (UnifiedModeling Language). Each tool has advantages and shortcomings, but it is a better way to generate system requirements automatically than manual work. Figure 1 represents the relationship between software engineering, requirements engineering, and requirements prioritization.

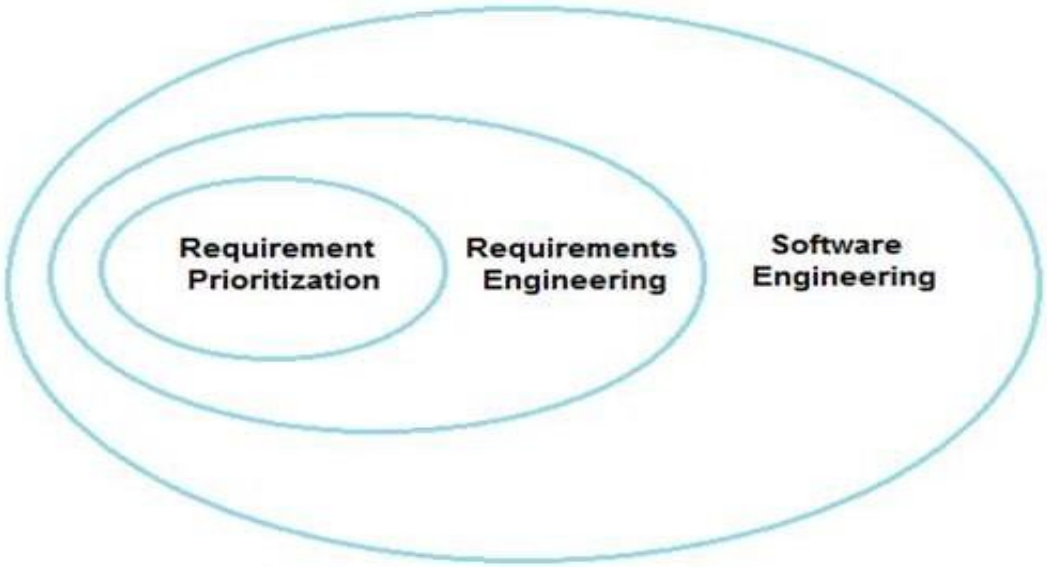

Figure. 1.
Relationship between software engineering, requirements engineering, and requirements prioritization.

Requirement gathering, analyzing, and prioritizing are massive tasks in which software engineers and analysts collaborate with stakeholders to find problemsand their solutions. Requirement elicitation is of greatsignificance in the requirement engineering field. Many approaches, such as walk-in interviews, surveys, and questionnaires, are used for requirement elicitation, (Baskaran, Saranya, 2014) but the problem of excessive user involvement and false requirement documentation is there. To get completeness and correctness in ourrequirements concerning stakeholders' needs, a technique must fill this gap and help in precise analysis. Requirement prioritization (RP) is one of the most significant exercises in this procedure. The software contains many requirements; these requirements should be organized because assets are restricted in spending plan and time, and consumer loyalty is the fundamental target insoftware improvement. Along these lines, partners' inclusion must be considered as they have to organize thesupplies as indicated by their significance with the goal that requirements can be requested in execution (Reddy, et al.,2017). The process of RP is worth a great deal of time and money as it eliminates unnecessary requirements that may cause high costs and helps select the most relevant requirements for each version.The significance of requirement prioritization lies in that it assists in succeeding plans, helps to reduce risks of redundancies and cancellation, regulates financial consequences of implementing each requirement, and, above all, can aid in Prioritizing investments in software products (Karlsson and

Ryan, 2018). Requirement prioritization is done timely and correctly; it leads developer toward the sensible execution of their business plan. It is impossible to execute all requirements at an equivalent time as requirements are not organized typically, and partners have varying perspectives towards the need of every requirement (Sharma et al.,2012). If requirements are not stated well, are incomplete, and are ambiguous, it will cause a profound negative impact on a software product (Garg et al., 2019). If requirements are inconsistent and the method chosen for prioritization is false, this delayed correction of errors may cost 200 times compared with timely correction and analysis.

Many requirement prioritization techniques are available that help developers and stakeholders organize their requirements in a timely and efficient. Software development is based upon specific criteria that some factors affect. As long as this factor affects criteria, the prioritization varies from one technique to another. The most critical criterion discussed in this paper is "value-based requirements", which is often neglected during prioritization of requirements. This study comes up with the introduction of four critical factors that affect the pre-defined set of criteria. The overall score calculation illustrates the change in criteria and requirement prioritization techniques. As criteria weight changes due to factors, the overall score of the requirement prioritization technique changes accordingly (Kukreja et al.,2013).

This process involves domain understanding & elicitation

- Requirements evaluation and negotiation
- Requirements specification and documentation
- Verification and validation of requirements

LITERATURE REVIEW

According to Summerville's statement, the most critical decision-making stage is requirement prioritization in any software development lifecycle. Firesmith stated it is a considerable process as it leads towards successful implementation of software products, guides to success with various versions, and allows the opportunity to apply required functional and non-functional requirements during development. For all these reasons, there is emerging interest in some organizations focusing more on requirement gathering and prioritizing them accordingly. (Lubars et al.,2018) stated in their review that many organizations believe that requirement prioritization should be done first to improve decision-making during product development.

Ahmad stated that if requirement analysis and choice are made in the right direction, it can contribute significantly to the software product's success. There are many techniques available for requirement prioritization (Achimugu et al., 2013). Each technique is designed so that it has specific pre-defined and systematic steps to rank requirements. As stakeholders associated with the specific product are geographically scattered, in such circumstances, prioritization of requirements gets complicated in new environments.

Karlsson et al. (2109) articulate that one of the biggest problems software developer's encounters is that the end product doesn't satisfy customers' expectations. The supporting article "Supporting the Section of Software Requirements" concludes the abovementioned concern: "The set of requirements selected for implementation is a primary determinant of customer satisfaction." According to (Minhas and Majeed, 2020),

requirement prioritization is a ranking process based on importance, and requirements should be tested continuously with every new software version in the development lifecycle. In software engineering, stakeholder satisfaction (primary or secondary) is considered a significant responsibility, specifically requirement engineering. Major concerns in requirement engineering are eliciting requirements, prioritization, and management. Prioritization of requirements helps sort out essential functional and non-functional requirements and choose high-value requirements for development (Kukreja et al.,2013).

Also, requirement prioritization helps achieve goals and resolve inconsistencies by providing a sustainable contract that satisfies all stakeholders engaged directly or indirectly. Parviainen stated that market conditions and demands are getting complex, and there is pressure to deliver the best product in every aspect, especially customer satisfaction, which is a critical point in this regard (Singh et al.,2011). There is an emerging trend in organizations that want to use available resources effectively, but the question is, which resource best satisfies stakeholders' needs?

To achieve goals in RE, many techniques have been proposed for requirement prioritization. The requirement prioritization techniques have limitations such as computational complexities, cost estimations, time constraints, technical limitations, inefficient human resources to use these techniques effectively, reliabilities of results, and scalability. Few of these techniques seem invalid for specific conditions, and some lack implementation support. These factors can primarily affect the software's success if considered during RE. To overcome these shortcomings, the communication gap between stakeholders and developers should be reduced, and the hiring of experienced human resources should be done so that requirement prioritization becomes easy.

According to Hoff, pre-defined core values can be considered during project planning, and it helps prioritize requirements. These core values are vital in improving stakeholder satisfaction and minimizing risk factors involved in software development. The core values proposed by Hoff include decision factors such as

- Cost-benefit and profit optimization,
- Error fixation
- Analyzing complexity
- Distinguish dependent and independent requirements
- Delivery time

It is essential to consider all these values while analyzing software requirements.

Two conceptual models were presented by Racheva in the review of requirement prioritization approaches and suggested five points that must be considered during the RP process

- Size and effort estimation
- Business values
- Learning Progress
- Potential risks
- Change from external factors.

Different requirement prioritization techniques are discovered from the literature survey, and it has been observed that the trend of using these techniques is potentially growing in the software development industry.

Requirement prioritization techniques

The preceding section emphasizes requirement prioritization, but it cannot be achieved without using techniques. Various requirement prioritization techniques have been proposed to increase the importance of requirement prioritization. "They also guide the decision-makers in analyzing requirements to assign them numbers or symbolsreflecting their importance." Some techniques emphasize that every requirement has a single priority, while fewtechniques categorize requirements by priority level.

AHP (Analytical Hierarchical Process)

AHP is a ratio scale technique known as the primary requirement prioritization method. A pairwise comparison of requirements is done in hierarchical order to prioritize requirements. For instance, if there are n number of requirements, n(n-1)/2 comparisons will be performed to prioritize requirements. Thistechnique assigns fixed individual values to each requirement and ignores requirement dependencies.

CV (Cumulative voting)

This technique has a second name, a hundred-dollar test, which assigns a fictional hundred units to potential stakeholder, and their responsibility is to assign units to requirements according to their priority. The critical problem of this technique is the absence ofscalability. It requires consideration of all factors mutually to prioritize one requirement.

Theory W

This technique implements four steps of cooperation to achieve a win-win situation. Therefore, it is not recommended forscalable projects.

Binary Search Tree

This technique prioritizes requirements in parent-child relationships. The prioritization of requirements is followed by analyzing all elicited requirements. It is fast and can scale thousands of requirements effectively.

Cost Value ranking

This technique prioritizes requirements by assessing cost value from an implementation point of view. This technique is time-consuming and not scalable for large projects. For the management of requirement interdependencies, complexity increases, and thus, its efficiency decreases gradually.

Top ten requirements

This technique lists the top ten requirements based on their relative importance. This technique is also not suitablefor scalable projects.

Importance of value-based requirements

A previously discussed literature review is focused on requirement prioritization and practical techniques for this purpose. The concern of value-based requirements is dominating in this research. According to Desmet and Hekkert, emotion plays a vital role

in interpreting a product or service. This appraisal or rejection for any project orservice happens automatically in people's minds due to their emotional attraction towards that service or project. Desmet emphasized this point by referencing Arnold's appraisaltheory, which consists of three main variables: Appraisal, goal,and stimulus (product).

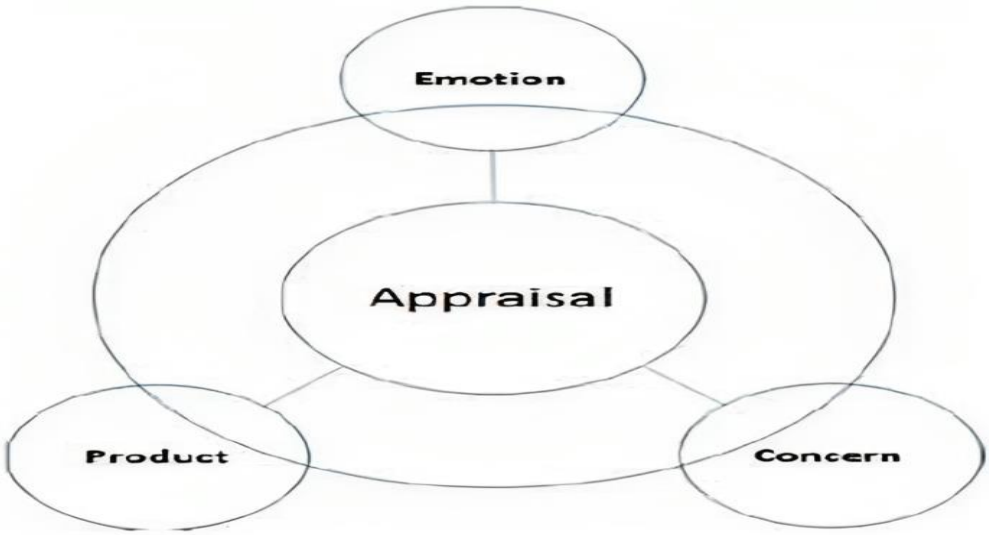

Fig. 2.
Desmet's Basic Model of Emotions

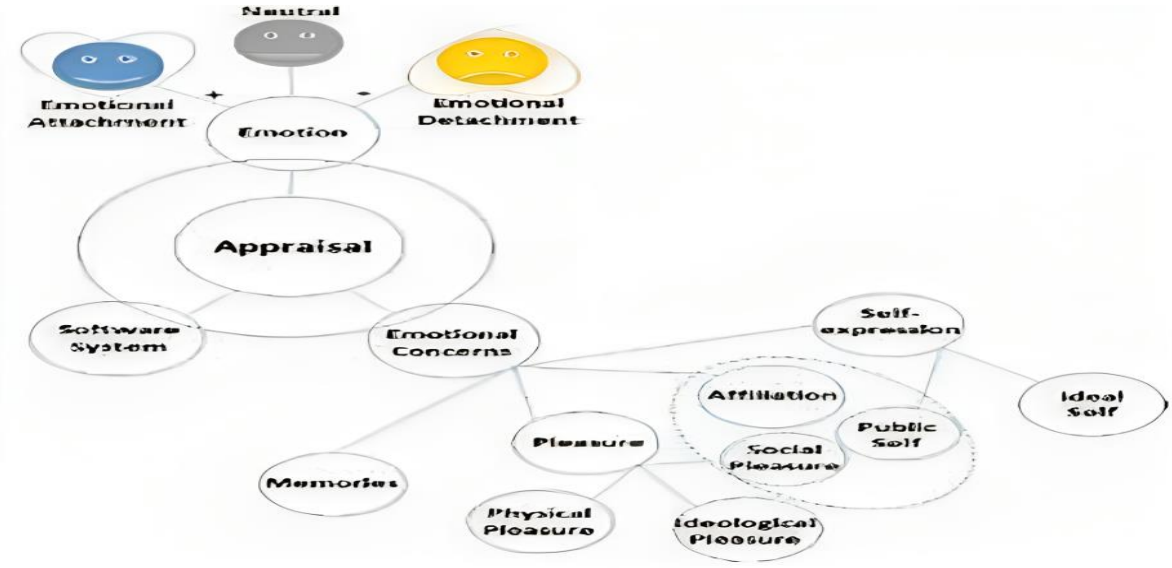

Figure. 3.
Emotional attachments Framework

People experience attachment to different services at different levels of abstraction. Their attraction towards a particular product or service may vary depending on their emotional needs and goals. Researchers are focused on analyzing people's emotional goals towards any system. Ramos and Berry

discovered fear factor which is involved in the acceptance of any new software system.

Hassenzahl named people's emotions a "hedonic quality." Hedonic quality is software capability to induce positive user experiences based on theiremotions. Thew and Sutcliffe highlighted the issue of poor understanding of stakeholders' emotional requirements, which eventually affect product acceptance. According to Norman's studies, the behavioral level of emotion is unconscious. Hestated it as "the highest level of feelings, emotions, and cognitionreside." Miller stressed in his study that emotional levels are often neglected in requirement engineering and practice, whichaffects software acceptance and success. In the end, Figure 3 represents EAF.

Figure 3 depicts that people's emotional goals are related to (i) self-expression, (ii) affiliation, (iii) pleasure, and

(iv) memories. As mentioned above, studies are focused on analyzing and interpreting emotional and functional requirements to provide a complete package of satisfactory products to stakeholders and customers.

Researchers have also discovered methods to compare different requirement prioritization techniques. Karlsson et al., (2016) discovered AHP as the most suitable technique for its efficient results based on the fault tolerance ratio scale among all other techniques. Hatton surveyed to rank different techniques, which include Moscow, hundred dollars, and AHP requirements prioritization techniques.

This research is intended to determine factors affecting requirement prioritization by considering five different techniques. Software development is based on some criteria, andthis study will light up the fact that calculated factors can affectthecriteria of software development, which will eventually affect the effectiveness of requirement prioritization techniques by calculating the overall score of each technique.

According to (Karlsson et al., 1998) a prioritizing comparison could consist of three consecutive stages: The Preparation Stage

In this stage, the individual structures the prerequisites as per the rule of the organizing procedure that could be utilized. Also, a group and a group leader were picked for the session andprovided considerable data.

a. The Execution Stage

In this stage, the chiefs characterize the genuine prioritization of the requirements dependent on the data from the earlier stage.

b. The Presentation Stage

It is a stage where the execution results are presented to the included people. Some prioritization techniques also include different types of computations that should be done before the results can be presented.

EVALUATION CRITERIA

The analysis is done based on some defined criteria. This includes accuracy of the result, ease of use, certainty/reliability, the ability of the method to scale up to more requirements, the Required number of comparisons, the Required time to make a decision, Complexity, Speed, Fault Tolerance, and Scalability, etc. These are some

evaluation criteria on which theanalysis of different requirement prioritization techniques is done depending upon the needs of the software to be developed.

Requirements Prioritization Techniques

Some of the well-known requirements prioritization techniques that will be used for comparison are given below

- Analytical Hierarchy Process (AHP)
- Binary Search Tree (BST)
- 100 Points Method (100PM) OR Cumulative Voting (CV)
- Value-Oriented Prioritization (VOP)
- Bubble Sort Method (BS)

Rationale and research goals

Calculations have already been done, and criteria are available that help rank requirement prioritization methods. This research aims to explore criteria focusing on value-based requirements, which primarily affect the prioritization technique's ranking by calculating the overall score. Most importantly, certain factors are mentioned in the literature survey. This research introduces two new factors and focuses on how value-based requirements, when added to criteria, affect the calculation of the overall score of requirement prioritization. This study imposes value-based requirements for a wide range of software products. Our primary focus is customer satisfaction, so we cannot neglect them while choosing a requirement prioritization method. In addition to these requirements, this study elaborates on the four critical factors' effect in calculating the prioritization technique's overall score. While considering these two essential aspects, this study proposes a better way to evaluate requirement prioritization techniques.

- Introduction of the framework, which focuses on factors and value-based requirements in ranking requirement prioritization method.
- Consider real-life projects and apply these factors and criteria to find the best requirement prioritization technique.

Factors Affecting the Prioritization Techniques

By comparing different techniques, conducting research in different industries, and looking at the requirements to developeffective software using requirement prioritization techniques,the following model/framework is proposed for "Factors and criteria affecting selection of Requirement Prioritizationtechniques."

These factors include

Resources of the stakeholders

- Qualification of analyst
- Experience as an analyst

- Capacity of the analyst to correctly interpret the analysis

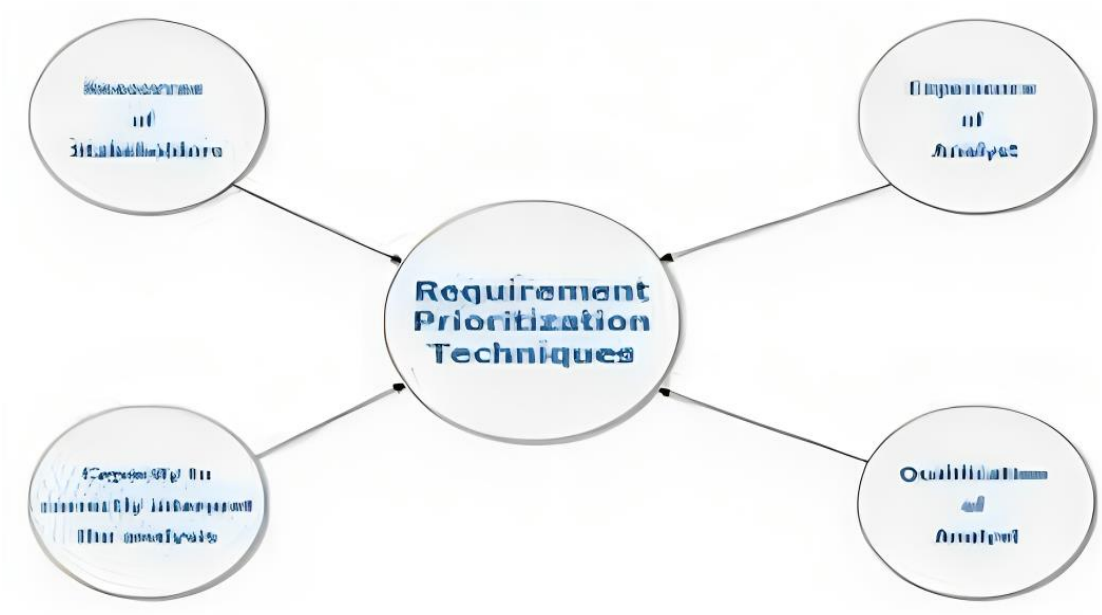

Figure. 4.
Proposed Framework for the Factors.

Resources of Stakeholders

The stakeholders' resources and their needs affect the requirement prioritization techniques for the development of effective software. The prioritization of prerequisites is essential to effective and result-oriented product improvement. Typically, partner desires are high; however, lack of time, restricted assets, and spending limitations make executing all prerequisites evoked for the framework hard.

In a few cases, prioritization of clients' requirements is troublesome as various clients have distinctive reasons and perspectives towards their software.

A most significant issue emerges when stakeholders are in diverse topographical territories. Their needs are not the same. Each requirement expert plays out the procedure of prioritization. Software engineers are not always prepared to evoke, assemble, dissect, and meet security requirements. Prerequisiteprioritization is amazingly risky in requirement designing. Without suitable prerequisite prioritization offered by various stakeholders, the critical targets of the final result can't be accomplished appropriately. The product may neglect to meet its heart targets based on a few requirements prioritization systems exhibited by various analysts.

Qualification of Analyst

The minimum qualification for the team leader or business expert isabachelor's degree. A study demonstrated that the in-house improvement industry attempts to procure at any rate single guy representatives for examination, requirements investigation, and prioritization, yet enterprises wanted business experts with splendid computer education like M.Sc.(CS) and so forth since their expert work includes answers to meet the client

business needs and client challenges.

To control and prioritize each of those requirements, the team leader ought to be highly qualified and have the capacity to interpret requirements into framework requirements with prioritization for software engineers

Instruction creates the capacity in examiner to comprehend the business requirements, distinguish those requirements, record those requirements and prioritized them for business application for software engineers.

Experience of Analyst

The analyst experience is second most important factor in software development. The analyst legitimately joins with clients and improves the prioritization of requirement. Analyst considers the source to construct the relationship to the client. The relationship might be email, phone calls, and face-to-face meeting. The analyst ought to lead powerful gatherings. Analyst should design the effective requirement. Analyst controls central reason examination and actualize the requirement prioritization exertion. The analyst makes surveys and prepares reports consistently to check the legitimate prerequisites. Analyst involvement with the remote client and group is also required. Administration must have understanding of both venture; the board as well as individuals. Analyst must have learning that product engineering and improvement is highly dependent on requirements prioritization. The analyst ought to be able to confront the elicitation and organize the prerequisites. Analyst should have the capacity to distinguish the requirements prioritization limitations.

Capacity of Analyst to Correctly Interpret the Analysis

For right understanding of interpretation of model capacity stability path is used. So as to get it more, intricate examination is required where the heap is connected to the model in additions and connection among burden and relocation of the model in every augmentation can be observed. Figure 5 shows factoring affecting weight.

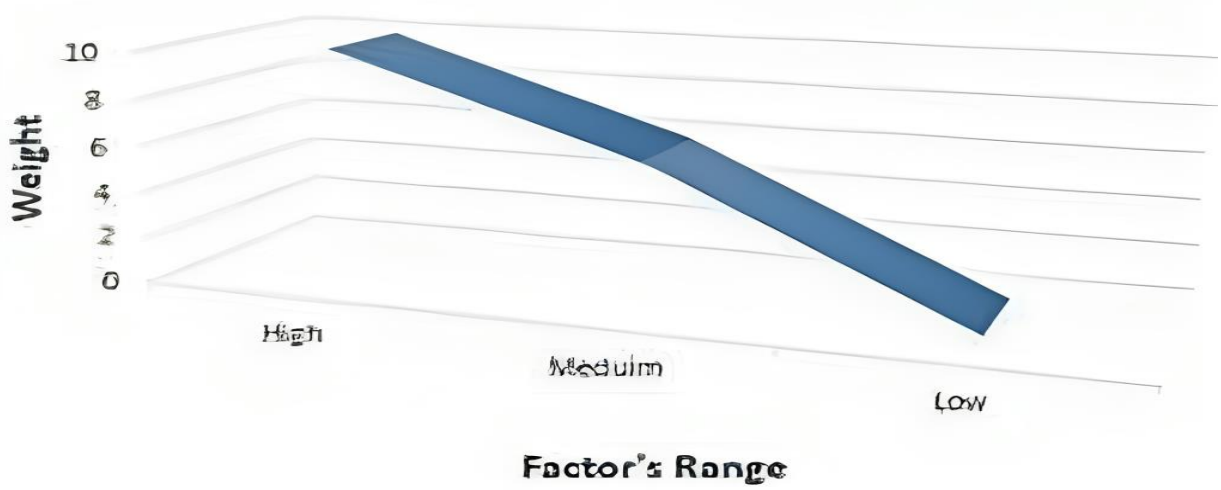

Figure. 5.
Factors affecting weight of criteria. (own code generated pic)

This Figure is used for illustration of effect of these four factors on evaluation criteria

discussed in experimental study. As long as these factors are changing, they are changing weighting of criteria for requirement prioritization technique.

$$Sij = W(Si) * ((N + 1) – Rci(Tj)) \quad \text{(Eq. A)}$$

Where

W(Si) is weight of criteria and

Sij is the score of technique i w.r.t technique j

So, when weight of criteria will be affected, it will affect overall score of technique calculated in 4.1.4 and hence selection

of appropriate prioritization method. It is clear from the above equation that the weight of the criteria is affecting the overall score of technique. Thus, due to the effect of the factors on different criteria, the weight of that criteria is changed and hencethe overall score of technique is affected.

Experimental Study

Since we have certain set of criteria to consider yet it was missing with important criteria which is value-based requirements i.e. how efficient a technique is in ranking of requirements that it considers both functional requirements and value-based requirements and prioritizes them as they meant tobe. To show the practical implication of these criteria industrialsurvey has been arranged. Participants of this survey were from quality assurance, project management, and requirement engineering team. Participants of this survey were given set of 20 requirements of two projects which are intended to enhance tourism in Pakistan and one of them is meant to improvise education system countrywide. Participants were allowed to rank them by using requirement prioritization techniques underconsideration. Time taken by participants and their responses were recorded orthogonally.

Table 1.
Weight Table for Criteria For Different Techniques.

Criteria	Weight for AHP	Weightfor BST	Weightfor CV	Weightfor VOP	Weightfor BS
Ease of Use	7	6	8	6	8
Accuracy	8.5	4	7	7	6
Scalability	8	5	7	6	4
Total TimeTaken	6	6	8	7	6
value-based requirements	7.5	4	6	8	5
Total	37	25	36	34	29

Table 2.
Weight Table For Criteria For Different Techniques For Project 2

Criteria			Weight for AHP	Weightfor BST	Weight for CV	Weight for VOP	Weightfor BS
Ease of Use			6	8	8.5	6	8
Accuracy			8	6	6	7	6
Scalability			7	6	7	6	4
Total Time Taken			7	7	8	7	6
value-based requirements			8	4	3	6	3
Total			36	31	32.5	32	27

ANALYSIS

They were asked to assign weight to these criteria and compare requirement prioritization technique under consideration. All participants were requested to pay attention on value-based requirements while assigning weight. The set of calculation received for tourism software are as follows in Table1. Criteria table for second project is as follows in Table 2. This survey was quite helpful to show that how criteria weight effect of value-based requirement on criteria of prioritization techniques.

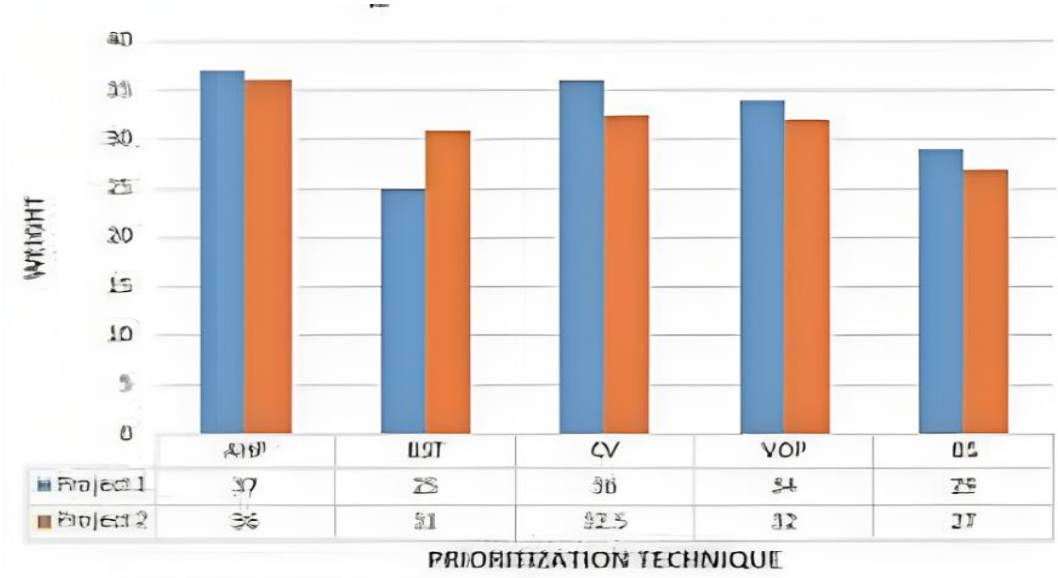

Fig. 6.
Effect of value-based requirements on criteria of prioritization techniques.

Figure 6 shows that the total weight of all criteria in requirement prioritization techniques in both project is different and so as the overall score of technique in both the project will also be different. This is the effect of value-based requirements on criteria of prioritization techniques. Since the weight of criteria changes in different techniques, the overall score of technique also changes. These weights have been shown using the calculations of Table 1 and Table 2 those are the weight Tables for Criteria for different techniques.

PROPOSED FRAMEWORK

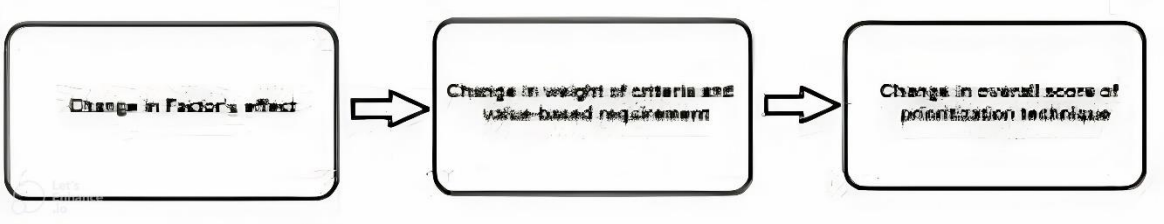

Fig. 7.
Proposed Framework

Figure 7 shows that the change in factors' effect changes theweight of criteria in different techniques. This results into the change in overall score of the technique as described in Eq. A that the change in weight of criteria results in the change in overall score of technique. While choosing a requirement prioritization technique, we look for the technique having maximum score of all techniques those are being analyzed. So each technique can have different scores due to the change in effect of the factors. This has been observed in the experimentalstudy.

Total No of Comparisons VS Prioritization Technique

In this comparison, prioritization techniques are ranked against the total number of comparisons. It means how much comparisons are required to analyze each technique.

The formula is given by

Total number of comparisons = $n(n-1)/2$

Where n is number of requirements.

The following formulas were used to calculate overall score for each of the prioritization techniques under consideration.

$Sij = W(Si) * ((N + 1) - Rci(Tj))$ [Except C2] (2) $Cij = W(C2) * ((N+1) * IsCertain(Tj))$

Where IsCertain = 1 if Tj has Certainity else IsCertain = 0

$OS(Ti) = \sum NC\ Cij / NC$

Where

N = Number of Techniques used NC = Number of Criteria

Sij = Score of Technique j in Criteria i C2 = Certainty

W (Si) = Weight of Ci

Rci (Tj) = Ranking of Technique j in Criteria i OS (Tj) = Overall Score of Technique j

The suggested technique is chosen by the following formula. [20].

Suggested technique= MAX (OS (T1), OS (T2)… OS(TN))

After performing these calculations on two different projects, effect of weight change in criteria due to value-based requirements and factors is clear and it is shown that it can affect selection of requirement prioritization technique proportionally. Difference in overall score in two projects is shown in Figure 8.

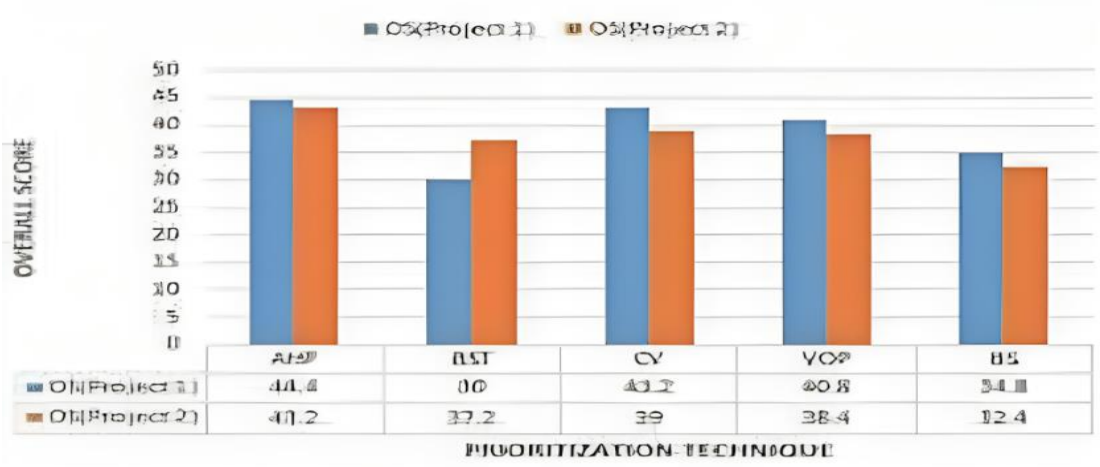

Fig. 8.
Difference in overall score of techniques for Project 1 and Project

Figure 8 represents the overall score of each technique in experimental study of Project 1 and Project 2. It can be observed that the overall score of each technique differs in both the projects. For example, the overall score of AHP technique in Project 1 is 44 while the overall score of same technique in project 2 is 43.2. So, it is clear that the overall score of a technique depends upon the weight of each criterion in that technique and that weight varies as the effect of factors varies for that particular criterion.

LIMITATIONS

By using the proposed method, only finite number of number of techniques by using this model. The factors and value-based requirements affecting the criteria can also change dynamically which can directly affect not only the weight of evaluation criteria but also the overall score of a prioritization technique and this may also lead to false results.

CONCLUSION

This paper describes factors and value-based requirements that affect the evaluation criteria of requirement prioritization techniques. The evaluation criteria are assigned ranking against the requirement prioritization techniques. They change when the factors are change; as a result, their ranking and weight are also affected. This results into the change in overall score of requirement prioritization technique. This work covers ranking of prioritization techniques with main focus on four factors and value-based requirements which are negligible in previous comparison studies. This study doesn't imply that these results are final. Since these factors and prioritization of value-based requirements may vary globally.

RECOMMENDATIONS

These techniques are not able to cover the requirement prioritization process in the field of global software engineering. So, there is need for doing more research in the field of global software engineering to overcome this problem. This will lead to the more advancement in the field of requirement engineering. This will also lead to the research needed in the field of global software engineering.

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Consent to Participate: Yes

Consent for publication and Ethical approval: Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

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