Requirements Prioritization Using Analytic Network Process (ANP)

Javed Ali Khan, Izaz ur Rehman, Liaqat Ali, Shapoor Khan, Yawar Hayat Khan, Iftikhar Javed Khan

Abstract— Software project development deals with many requirements. Since software is developed in different increments, it is difficult for requirement engineers to implement all these requirements in one single increment. For this purpose, prioritization of requirements is essential in order to deliver right product on right time. A thorough survey of literature depicts that no requirements prioritizing methodology prioritizes dependent requirements. Moreover, performance of existing methodologies regarding requirements prioritization needs improvement. During the literature survey, most of the prioritization methodologies were studied and critically reviewed. After analyzing different techniques, a new requirements prioritization methodology is proposed and a model is developed that can prioritize both dependent and independent requirements. The interdependent requirements will be prioritized with newly proposed requirements prioritization technique that is Analytic Network Process (ANP). The simulation results of the proposed technique showed that ANP produced finest outcomes for prioritizing requirements. The simulations were carried out in MATLAB software.

Index Terms—. Requirement Engineering, Prioritizing requirements, Analytic Network Process, Analytic Hierarchy Process, Software Engineering.

1 INTRODUCTION

In software product development, often confronts with a situation where one has to make a decision for selection among several available choices of requirements [1]. Software projects usually have hundreds or thousands of requirements.

In software development, requirement prioritization is very important and it is carried throughout the development cycle. [12].The software projects have certain limitations regarding time, budget and resources. Because of these limitations, all requirements cannot be implemented in one release or increment. Therefore, requirement engineer and stakeholder should prioritize requirements and must be implemented in the first release.

Software project where only one stakeholder is involved in requirements prioritization process is manageable however it is difficult to manage when many different stakeholders are already involved. Prioritizing requirements is viewed as a standout amongst the most vital and irreplaceable procedures of software development [2]. These requirements prioritization methods provide a lot of help and facilities in developing software products. Still there exist some shortcomings in these requirements prioritization techniques. Picking up wrong requirements do not only produce a meaningless effort but also increase exertion on next increment which increases the chances of project failure [16]. The main problem with all requirements prioritization techniques is that none of prioritization techniques supports prioritization of interdependent requirements. Requirements are usually interdependent upon each other. A software requirements prioritization technique will be used in managing a huge number of software requirements which also support prioritizing of dependent requirements. FBI Virtual Case File project is an example of a large software venture. Its financial plan was 170 million dollars [3]. Conflicts occurred amongst stakeholder can be resolved through prioritization [13]. Mobasher, et. al. did investigation of Virtual Case File project and suspected that disappointment of the task some way or another happened because of the blunder of requirements and additionally lack of prioritizing requirements [4]. Apparently, all requirements are not essential for stakeholders therefore prioritization is required within the constraints of limited resources (cost, time and user satisfaction). [15].Competitors accessible in business sector should undertake within the designated time and spending plan software product advance completion is said to be essential also. Consequently, a simple, straightforward, proficient, dependable and flaw tolerant prioritizing methodology should be utilized. Prioritizing methodology must bolster prioritization of interdependent requirements. So far, prioritization techniques which have been developed do not support prioritization of interdependent requirements. Also, the performance of existing prioritization techniques did not show any mark up. It still needs some improvements. The ANP and AHP are two numerical methodologies for prioritizing requirements. AHP is used to separate expansive unstructured issues into manageable and quantifiable procedures. ANP is the general type of AHP and is capable to manage compound choices where relationship exists in a choice model. Regardless of the expanding number of utilizations of AHP in various fields that involve basic decision making, ANP has begun to be occupied with prioritizing requirements in software engineering fields. Although no research done presents the utilization of ANP in a common requirement prioritization process.

The rest of the papers are formatted as follow: Section-2 elaborates the related work.Section-3 elaborates the detail

- *Javed Ali Khan is with the UST Bannu in the Department of Software Engineering, Pakistan.E-mail: engr_javed501@yahoo.com.*
- *Izaz ur rehman is with the UST Bannu in the Department of Software Engineering, Pakistan.E-mail: izazur.644@gmail.com.*
- *Liaqat Ali is with the UST Bannu in the Department of Electrical Engineering, Pakistan.E-mail: engr_liaqat183@yahoo.com.*
- *Shahpoor Khan is with the UST Bannu in the Department of Software Engineering, Pakistan.E-mail: shahpoor31@gmail.com.*
- Yawar Hayat Khan is with the UST Bannu in the Department of Electrical Engineering, Pakistan. E-mail: hyyat303@ yahoo.com.
- Iftikhar Javed Khan is with the UST Bannu in the Department of Electrical Engineering, Pakistan.E-mail: engineer_iftikhar169@yahoo.com.

algorithm of proposed requirement prioritization technique. Section-4 explains the case study that elaborates proposed technique and Section-5 states the conclusion with some future directions.

2 Literature Review

During requirement phase, giving importance to one requirement over another is useful in completing the project in defined schedule. This practice is referred as requirements prioritization [18].There have been different definitions given by different scholars pertaining to requirements prioritization. It can be defined in the context of software requirements that will be included in certain iteration or in the development of a product. According to Summerville, software requirements prioritization is a process during which the most critical requirements are identified [5]. According to Firesmith [1], software requirements prioritization is the activity which determines the sequence of the implementation of the requirements to be developed in the system or the process to know the sequence of critical requirements to the stakeholders. According to Gilb and Maier, priority is comparative right of a requirement to the consumption of specific resources [6]. Firesmith [1] saw that software framework is comprised of hundreds or a large number of software requirements. Requirements prioritization additionally evacuates the difference amongst the diverse stakeholders as they agree to common point by negotiation on the conflicted requirements. Karlsson and Ryan argue that requirements prioritization recommend stakeholders to appoint assets to requirements on the premise of their needs. [7]. Karlsson and et. al. call attention on knowing the issues of the requirements prioritization like misconception of requirements or any questionable requirement with the goal of finding out that it doesn't represent any issue later on [8].Different stakeholders can be agreed on conflicting requirement with the help of prioritization [14]. Hatton reports that requirements prioritization is currently imperative in software development for the successful completion of projects so as to decrease the failure rate of the projects [9]. Usually, developers and stakeholders define requirements for prioritization [17].

When developing a project, there are factors to be considered namely: the implementation of tight schedules, a specified timing, limited cost and specific human resources. While developing a product, it must contain many requirements that will be developed in one increment of the project/product. After thorough examination the stakeholders will determine and decide which requirements are important to be included in the release of the product then requirements prioritization takes place. It helps stakeholders distinguish which requirements must be included in the release with resource constraints. A single stakeholder easily identifies essential requirements than multiple stakeholders in calculating priorities. Opposing views and opinions may mislead the adaption of most essential requirements when various stakeholders are involved. For example, one developer will implement a particular requirement that will take less time on the other hand, the finance manager will take another requirement that will cost less, the marketing manager will prioritize such a requirement that will have high market value and the end user will take such a requirement that is easy to use. Fig 1 shown above represents the structure of Requirement prioritization where it comprises criteria bunches and alternative bunches. There is a feedback amongst alternative criteria bunches that compares criteria cluster with alternatives. The loops in criteria bunches demonstrates that the hubs in it are contrasting among themselves. ANP model is appropriate to select the

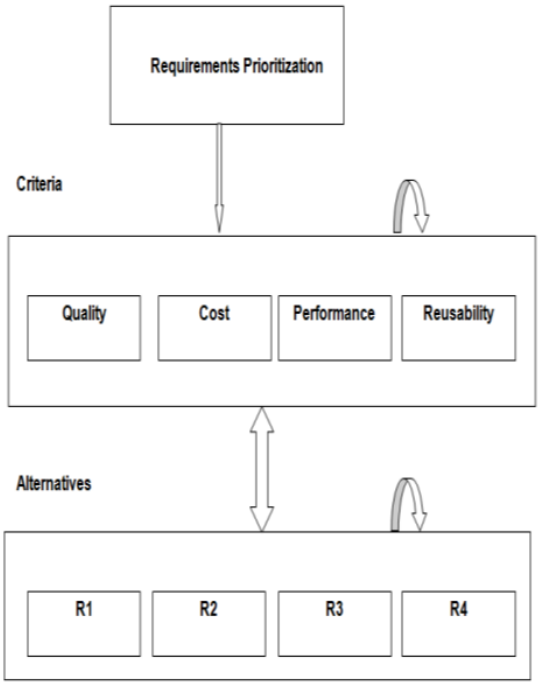

Fig. 1. Framework for the selection of requirements

Intensity	DEFINITION	Explanation
1	of equal value	Two requirements are of equal value
2	Slightly more value	Experience slightly favors one requirement over another
5	Essential or strong value	Experience strongly favors one requirement over another
7	Very strong value	A requirement is strongly favored and its dominance is demonstrated in practice
9	Extreme value	The evidence favoring one over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between adjacent judgments	When compromise is needed

Fig 2: Pairwise comparison scale for ANP [13].

priority requirements.

3 ALGORITHEM

There are models which are being proposed to discuss before prioritizing the interrelated requirements. The following steps below discuss the need of requirement prioritization and the criteria underlying the evaluation of these requirements.
The model is described in steps below:

Step 1: The first step is the requirement gathering for the product or project and assign priorities to them from different stakeholders in the organization. Saaty [10] recommended the utilization of a nine-point scale and Pairwise examination.
Step 2: After identifying the requirements gathered from the stakeholders prioritization will follow in order to develop right product in a right time. Since not all requirements cannot be implemented in one time criteria are set to determine based on the stakeholders discussion.
Step 3: In this step actual requirements are identified and alternatives are being named. These requirements will be prioritized on the basis of the criteria that have been identified before.
Step 4: In the fourth step the requirements that are similar are placed in the same cluster which are called elements of the clusters. These clusters are also known as criteria. Now in this step the relation between the different clusters and the alternatives are identified.
Step 5: In this step, eign vectors are calculated by Pairwise comparison for each element of develop matrix.
Step 6: Now, measure the inconsistency of the matrices that have been derived for the requirements. Elements are compared through Pairwise Comparison Matrix by employing the consistency ratio. Saaty arranged three satisfactory degrees for Consistency Ratio (CR) (i.e. 0.05 for 3x3 matrix and 0.08 for 4x4 matrix and 0.01 for other matrices). Inconsistent matrices must be removed or re-rated by the raters or the stakeholders involved in the prioritization of the requirements.
Step 7: As all the possible matrices are identified, now place the Eigen vectors of the single matrix to form the super matrix.
Step 8: Finally the super matrix will be at steady state by multiplying the weighted super matrix by itself until super matrix row values converge to the same value for each column of the matrix.

4 ANP MODEL FOR REQUIREMENTS PRIOIRITIZATION

Details procedures of ANP can be found in Saaty [10] however the primary strides are outlined underneath.

4.1 Pairwise correlations on the components and reative weight estimation

Making Pairwise comparison of the elements in each level one can get the relative weights of elements in ANP. Pairwise correlation is achieved in reference to their comparative significance regarding with their control criterion based on the characteristics of AHP and evaluates using Saatys scale as shown in Fig 2. The score of aij in the Pairwise correlation matrix

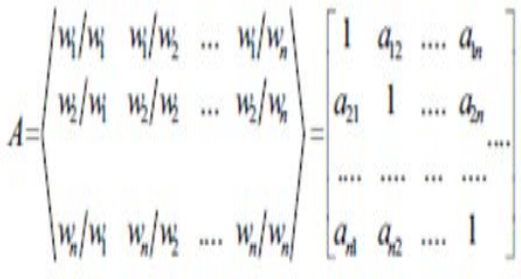

Fig. 3. General form of the comparison matrix [11].

demonstrates the relative hugeness of the component on row (i) over the component on segment (j),i.e.,aij=wi/wj .
According to any criterion, the Pairwise comparison is done at two different levels as the component level and the cluster level.
So if there are no components to be analyzed, the subsequent correlation matrix A is shown in the Fig 3.
After the Pairwise comparisons, determine the eigen vector by the relation
$Aw= \lambda_{max} w$
Where λ_{max} is the biggest eigen estimation of matrix A and w is its eigen vector.
The consistency index [CI] and consistency ratio [CR] of the Pairwise correlation matrix could then be dictated by:
CI = λmax - n/n-1 , CR=CI/RCI
Where n is the arrangement of comparison matrix.
RCI being a Random Consistency Index gave by Saaty. By and large, if CI is under 0.1, the judgment can be considered as reliable.

4.2 Developing the genuine supermatrix (unweighted supermatrix)

The relative noteworthy weights (Eigen vectors) obtained from the Pairwise comparison of the elements of the ANP are placed within the super matrix. That represents the dependence among all the elements of the network. The general type of the super matrix is depicted in Fig 4, where Ci demonstrates the ith group, eji speaks to the jth component of the ith bunch and Wik is a lump network, containing priority weight vectors of the reliance of the components in the ith bunch as per the kth bunch.

Fig. 4. The Super Matrix of Network [11].

4.3

Developing the Weighted Super Matrix

The weighted super matrix is developed by weighing the block of the unweighted super matrix with the help of relative dependence of the cluster on the control criterion. So the super matrix becomes the column stochastic matrix. Again by standard AHP perform the weighted of the clusters.

4.4 Developing the Weighted Super Matrix

The weighted super matrix will be advanced to constraining powers so that the weights meets and gets to be steady then the point of confinement super matrix will be gotten. In limit super matrix each column in every row will have same value.

5 Case Study

To prioritize the dependent requirements, take a general scenario of requirements. Having four (4) requirements R1, R2, R3, R4 which are considered as alternatives and four criterions under which each requirement will be evaluated. The four alternatives are cost, quality, performance and reusability. These are called criterion. In our case each requirement depends upon each criterion and vice versa. Similarly each criterion depends upon each requirement and vice versa. This has been shown in the Fig 1.

Fig 1 shows that the goal of the network is requirement prioritization. Goal can be achieved by prioritizing the requirements using ANP.

Various comparison matrices according to the calculation are registered and given as takes after:

TABLE 1
With Respect TO Prioritiy

	Quality	Cost	Performance	Reusability	E.V
Quality	1	2	3	½	0.2771
Cost	½	1	2	1/3	0.1611
Performance	1/3	1/2	1	¼	0.0962
Reusability	2	3	4	1	0.4663
					CR = 0.0006

TABLE 2
Related TO Quality

	Cost	Performance	Reusability	EV
Cost	1	2	1/3	0.2391
Performance	1/2	1	¼	0.1371
Reusability	3	4	1	0.6231
				CI =0.016

TABLE 3
Wtih Respect TO Cost

	Quality	Performance	Reusability	EV
Quality	1	3	½	0.3201
Performance	1/3	1	¼	0.1224
Reusability	2	4	1	0.5567
				CI =0.020

TABLE 4
Related TO Performance

	Quality	Cost	Reusability	E.V
Quality	1	2	½	0.2967
Cost	1/2	1	1/3	0.1623
Reusability	2	3	1	0.5389
				CI =0.0033

TABLE 5
With Respect TO Reusability

	Quality	Cost	Performance	E.V
Quality	1	2	3	0.5389
Cost	1/2	1	2	0.2967
Performance	1/3	1/2	1	0.1634
				CR =0.0090

TABLE 6
With Respect TO Quality

	R1	R2	R3	R4	E.V
R1	1	9	8	3	0.5567
R2	1/9	1	1/6	1/9	0.0356
R3	1/8	6	1	1/6	0.1056
R4	1/3	9	6	1	0.3000
					CR = 0.2455

TABLE 7
With Respect TO Cost

	R1	R2	R3	R4	E.V
R1	1	6	4	8	0.5900
R2	1/6	1	1/3	3	0.1167
R3	¼	3	1	5	0.2378
R4	1/8	1/3	1/5	1	0.0523
					CR = 0.0811

TABLE 8
With Respect TO Performance

	R1	R2	R3	R4	E.V
R1	1	3	5	3	0.5189
R2	1/3	1	3	1	0.2011
R3	1/5	1/3	1	1/3	0.0789
R4	1/3	1	3	1	0.2000
					CR = 0.020

TABLE 9
Related TO Reusability

	R1	R2	R3	R4	EV
R1	1	1/4	1	1/5	0.0889
R2	4	1	4	1/2	0.3189
R3	1	1/4	1	1/5	0.0889
R4	5	2	5	1	0.5011
					C R = 0.0090

TABLE 10
WITH RESPECT TO R1

	Q	C	P	R	E.V
Q	1	1/4	1	1/5	0.0889
C	4	1	4	1/2	0.3189
P	1	1/4	1	1/5	0.0889
R	5	2	5	1	0.5011
					CR = 0.0090

TABLE 11
With Respect TO R2

	Q	C	P	R	E.V
Q	1	1/7	1/8	1/9	0.0378
C	7	1	2	1/3	0.1878
P	8	2	1	½	0.2934
R	9	3	2	1	0.4778
					CR = 0.0429

TABLE 12
Related TO R3

	Q	C	P	R	E.V
Q	1	1/4	1	1	0.1423
C	4	1	4	4	0.5711
P	1	1/4	1	1	0.1423
R	1	1/4	1	1	0.1423
					CR = 0.0080

Table 13
With Respect TO R4

	Q	C	P	R	E.V
Q	1	7	4	2	0.4923
C	1/7	1	¼	1/6	0.0512
P	1/4	4	1	1/3	0.1412
R	1/2	6	3	1	0.3111
					CR = 0.0488

So, limit matrix (shown in TABLE 15) is constructed from weighted super matrix (shown in TABLE 14) and we have also obtained the final priorities of the requirements as.

R1= 0.1404, R2 = 0.0538, R3 = 0.0402 and R4=0.0975

So, from the point of limit matrix it is made obvious that R1 among every one of the choices has most elevated weight i.e 0.1404, consequently it has highest priority and will be implemented first.

Table 14. Wighted Super Matrix

Cluster Nodes Labels		Prioritizes	Criteria			Alternative			
		Prioritizes	Q	C	P	R	R1	R2	R3	R4
Prioritize	Prioritizes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.0000
Criteria	Q	0.2771	0.0000	0.3196	0.2969	0.5396	0.4735	0.0378	0.1428	0.4964
	C	0.1600	0.2385	0.0000	0.1634	0.2969	0.3259	0.1853	0.5714	0.0509
	P	0.0954	0.1365	0.1219	0.0000	0.1634	0.1564	0.2956	0.1428	0.1393
	R	0.4672	0.6250	0.5584	0.5396	0.0000	0.0440	0.4812	0.1428	0.3132
Alternative	R1	0.0000	0.5696	0.6034	0.5222	0.0889	0.0000	0.0000	0.0000	0.0000
	R2	0.0000	0.0328	0.1114	0.1998	0.3182	0.0000	0.0000	0.0000	0.0000
	R3	0.0000	0.0930	0.2344	0.0780	0.0889	0.0000	0.0000	0.0000	0.0000
	R4	0.0000	0.3044	0.0506	0.1998	0.5039	0.0000	0.0000	0.0000	0.0000

Table 15. Limit Matrix

Cluster Nodes Labels		Prioritizes	Criteria			Alternative			
		Prioritizes	Q	C	P	R	R1	R2	R3	R4
Prioritize	Prioritizes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.0000
Criteria	Q	0.2156	0.2156	0.2156	0.2156	0.2156	0.2156	0.2156	0.2156	0.2156
	C	0.1475	0.1475	0.1475	0.1475	0.1475	0.1475	0.1475	0.1475	0.1475
	P	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975
	R	0.2033	0.2033	0.2033	0.2033	0.2033	0.2033	0.2033	0.2033	0.2033
Alternative	R1	0.1404	0.1404	0.1404	0.1404	0.1404	0.1404	0.1404	0.1404	0.1404
	R2	0.0538	0.0538	0.0538	0.0538	0.0538	0.0538	0.0538	0.0538	0.0538
	R3	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402	0.0402
	R4	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975	0.0975

6 Conclusion and Way Forward

Most of the prioritizing methodologies were studied to know its difficulties and limitations when doing prioritization of requirements. Few difficulties and limitations were identified in previous methodologies i.e. not a single methodology was able to prioritize interdependent requirements and its performance is also not good. The problem of delivering reliable and fault tolerance results occurred. Therefore, the development of requirements prioritization technique is very much needed in such a way that both dependent and independent requirements are being prioritized.. Detail steps of ANP described how requirement prioritizes through ANP. The dependency between and among the requirements that has been established is greatly considered to define which priority of inter dependent requirements are calculated.

Our evaluation found out that ANP is the most reliable technique among the available requirements prioritizations strategies. ANP provides reliable and fault tolerance results. Complexity can be overcome with the development of tool for ANP. ANP produces most solid results which depend on proportion scale. ANP is flaw tolerant. ANP incorporates consistency check. On the other hand, AHP although also includes these features failed to calculate the priority of interdependent requirements. Karlsson, et. al.[18] has proposed AHP as the preeminent strategy.Shah, et. al. applied ANP in the selection of design component and produce better results than existing techniques [19]. Javed,, et.al.did comparison of ANP with existing requirement prioritization techniques, ANP provides enhanced results [15].Similarly, Babu, et. al. used ANP for selection of architecture styles in order to fasten software architecture [20]. Pandey, et. al. get better results with ANP when applied in software testing for component selection [21].

ANP is completely based on AHP but the only difference is that it calculates the priority of interdependent requirements better than AHP does. Members simply and totally comprehend first the requirements while doing prioritization using ANP, identify and determine the relationship between and among the requirements and criteria undertaken to be prioritized. This follow to have a clear framework which can be easily understand thus avoiding unnecessary stretch. Therefore a conclusion has come up from the study conducted to undergo extensive research in order to enhance the performance of ANP.

Future work will focus on the deployment of newly proposed technique (ANP) to industry, so that industrial projects of software could be prioritized by ANP. Performance of ANP will be checked thoroughly as well when prioritizing requirements in industry.

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