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RESEARCH ARTICLE

SIGNIFICANCE OF MCCALL'S QUALITY FACTORS IN SOFTWARE ENGINEERING: A QUANTITATIVE APPROACH

***,[1]Kothuri Parashu Ramulu and [2]Ramana Murthy, B. V.**

[1]Research Scholar, Rayalaseema University, Kurnool, Andhra Pradesh, India
[2]Professor, Stanley Engineering College for Women, Hyderabad, Telangana State, India

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ABSTRACT

Requirement engineering is the important phase in software development life cycle process. The objective of requirement engineering is to discover and collect the functional requirements and non-functional requirements. The requirement engineering performs the critical role in analyzing and prioritizing the McCall's quality factors based on its necessity and feasibility. Requirement engineering makes complex decisions about the requirements prioritization in software development process to maintain the quality software. Selecting and prioritizing the proper non-functional requirements from the multiple requirements is a critical task. The Analytical Hierarchy process (AHP) is a multi-criteria decision making method provides an effective quantitative approach for prioritizing the requirements of McCall's quality factors in various feasibility criteria's. The objective of the paper is to evaluate the prioritization of requirements in McCall's Quality factors based on feasibility criteria's using the AHP.

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INTRODUCTION

Software industry still suffering low success rates. As per the Chaos Report 2009, iindicating only 32% of all projects are "successful" in the sense they are delivered on time, on budget, and with the required features and functions. 44% are described as "challenged" meaning they are delivered late, over budget, and/or with less than the required features and functions, the remaining 24% failures, being terminated before completion or delivered but never used. Ten main factors causing challenged or failed projects are unveiled. Four of them are lack of user involvement, lack of resources, unrealistic expectations, and changing requirements and specifications. Requirements prioritization increases user involvement by letting the stakeholders decide which requirements the project should contain. It helps stakeholders hold realistic expectations by letting the stakeholders understand the current constraints, resources and conflicting perspectives. The software engineering approach is to develop the software products within the time, budget and with more quality. The software developed in systematic, disciplined and measurable manner starts with various phases like requirement analysis, progresses with design, construction and concluded with deployment. The various process models supports same phases but the way of approach is different. Requirement Analysis is primitive and foundation phase of the software development life cycle with its own role. Requirement analysis is a systematic approach which collects the stakeholder requirements from the different sources and converting into design specific. It is a socio technical multidisciplinary acidity for requirement gathering as well patterns of social interaction between user and requirement engineer. There is dominant impact of this phase is on the development of software product quality. The requirement engineering involved with various activities like understand the customer wants, analyzing its need, accessing its feasibility, negotiating of right solution and converting into operational system. The software projects have many requirements based on domain and its scope. The various stakeholders of the system have many views on requirement. All the requirements not considerable to pursuable. The requirement engineer often face the complex situation where the decision making taken place in selection and prioritization of requirements from multiple on different criteria. The prioritization of requirements based feasibility study and necessity, it minimizes the stakeholder unsatisifaction and failureness of the software with intent of the quality. The errors formed in this phase will be continued to the later phases of the software development. The rectification of errors in this phase is easy in cost and time wise than the later stages of development. So, Analytical Hierarchy Process is a suitable quantitative approach for such types of problems. This paper

Corresponding author:* **Kothuri Parashu Ramulu,
Research Scholar, Rayalaseema University, Kurnool, Andhra Pradesh, India.

presents the requirement prioritization with respect to the feasibility. The organization of the rest of the paper is as follows. The Section 2 describes the related literature which focuses on the prior work on requirement engineering. The section 3 states the prioritization with respect to feasibility study. The section 4 presents prioritization of McCall"s quality factors using AHP. Finally concluded with future scope in the Section 5.

Related work

Over the years the researchers have worked on domain of requirement engineering in software engineering.This taxonomy can be useful in extensive research and knowledge discussion in the area requirement prioritization. The good number of researchers provided key research contributions in the area of requirement engineering is as follows.

- Pressman (2001) describe that, the software engineering is a systematic, and well defined approach which encompasses processes, management methods and tools in order develop the software products in the various domains.
- Reifer (2003) expressed that, the impact of requirement engineering is on the various development activities likes design, testing, software maintenance and evolution.
- Zave (1997) discussed that requirements engineering is one of many domains in software engineering concerned with the real-world functional requirements and its constraints
- Bergman and Klefsjö (2003) presented that the challenge faced with software engineering is whether the software system truly reflects the customers' needs or not.
- Doerr et al. (2007) defined that, the challenge faced with software engineering is whether the software system truly reflects the customers' needs.
- Nuseibeh and Easterbrook (2000) illustrated that requirements prioritization is critical activity in the requirement engineering process incorporated with decision making to develop the software products.
- Zowghi and coulin (2005) note that, requirements elicitation is first steop of requirements engineering concerned with learning and the understanding of the stakeholder requirements .
- Goguen and Jirotka (1994) says that, requirements can be gathered with right questions from different sources and then it will be eliicitated. .
- Machado et al. (2005) mention that, the stakeholders have various view points on requirements. The user requirements can transformed as system requirements.
- Thayer and Dorfman (1997) noted that, a variety of documentation standards have been provided guidelines for understandability and readability of software requirement document.
- Gotel and Finkelstein (1994) described that, requirements traceability traces the life of a requirement in both forwards and backwards directions in order to analyze the consequences and impact of change.
- Lehtola et al. (2004) suggest that, requirement prioritization needs to be taken iteratively through the entire software development process to maintain resources and consistency up to date.
- Hatton (2008) advises that in the early stage of the requirements engineering process, large numbers of requirements are likely to be added from the clients' side. Clients may have a general idea of what they want, but they may not have a clear idea of what exactly they want.
- Maiden (2008) refers that, a user requirement as an instruction which a user provides that expresses a property of a domain or a business process that a new system will bring about.
- Jogannagari Malla Reddy and S.V.A.V. Prasad presented the archetypal approach on requirement engineering process activities. The researchers highlighted the role of requirement engineering process with intent of software quality in the software development.
- Sommerville (1996) defines that, requirements prioritization is an activity can highlights the most feasible requirements which can be pursuable.
- Sadia Rehman and Siffat Ullah Khan describe that, "the software metrics and its role in global software development with systematic literature".
- According to Tom Demcrio "We need not control what we can't measure". The software quality models can control and monitor the software development process.
- Rawat and A. Mittal highlighted on views on software quality. The many software models, metrics have developed, utilized resulting with remarkable development of successful software.

Requirement prioritization of mccalls' quality factors with respect to feasibility

Requirement prioritization and selection is crucial activity in the elicitation process of the Requirement engineering. The system utility is determined by its functional and non functional requirements. The functional requirements are defines as its functionality and its services. But non functional requirements are quality constraints, which are defined on the functional requirements. The failureness of non functional requirements leads entire system is useless and unworthy. This research paper mainly highlights the Prioritization of following McCall's quality factors based on feasibility study on various stakeholder views such as user, manufacturer, product and value based view.

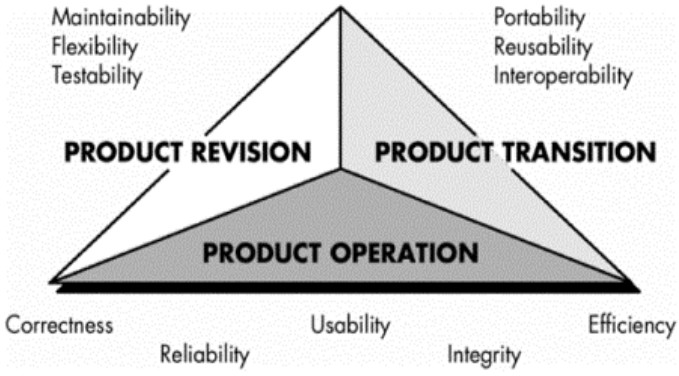

Figure 1. Classification of McCall's Quality factors

McCall identified the eleven quality factors classified into following three perspectives,

Product revision (ability to Change): It defines the quality factors that that influence the ability to change the software product. Example Maintainability, Flexibility, Testability etc.

Product transition (adaptability to new environment): The product transition identifies quality factors that influence the ability to adapt the software to new environments. Example: Portability, Reusability, Interpretability etc.

Product operations (Basic Operational characteristics): It identifies the quality factors that influence the extent to which the software fulfils its specifications such as Correctness, Reliability, Efficiency, Integrity and usability.

The above eleven quality attributes, each attribute is little bit more are less than other. The stakeholder views and perspectives are different in estimating the quality factors. The quality software is cost and operational effective than the lack of quality one. The lack of quality software requirement speciation can lead to develop lack of quality software development intensive system and face the stakeholders unsatisfaction in terms of time, cost and efforts. Feasibility study is a primary analysis of any project, which feasibility elements of knowledge that indicate if a project is worthy or not for development. A feasibility study estimate the level of possibility required to develop the system. This analysis can estimates its necessity with quantitative and qualitative assessments of other resources, identification of critical points. The critical study represent the historical background of the business or project, a description of the product or service, accounting statements, details of operations and management, marketing research and policies, financial data, legal requirements and tax obligations. The study on following economical, operational, technical, Legal and schedule aspects of the system which is going to develop. Economical Feasibility: It helps organizations assess the viability, cost, and benefits associated with projects before financial resources are allocated. It also serves as an independent project assessment, and enhances project credibility, as a result. It helps decision-makers determine the positive economic benefits to the organization that the proposed system will provide, and helps quantify them. This assessment typically involves a cost/ benefits analysis of the project.

Operational Feasibility: It involves in undertaking a study to analyze and determine whether the business needs can be fulfilled by using the proposed solution. It measures how well the proposed system elevates the problems and takes advantage of the opportunities identified during its definition scope. The feasibility studies also analyze how the project plan satisfies the requirements identified in the requirements analysis phase of system development. To ensure success, desired operational outcomes must inform and guide design and development. These include quality attributes such s reliability, maintainability, supportability, usability, disposability, sustainability and affordability.

Technical Feasibility: The assessment is focuses the the technical strength of the organization. It helps organizations asses if the technical resources meet capacity and whether the technical team is capable of converting the ideas into working systems. It evaluates the hardware and software requirements of the proposed system.

Legal Feasibility: The study investigates if the proposed system conflicts with the legal, ethical, assembly procedures and standards.

Scheduling Feasibility: The scheduling feasibility is the most important for project success. A project will fail if not completed on time. In scheduling feasibility, we estimate how much time the system will take to complete, and with our technical skills we need to estimate the period to complete the project using various methods of estimation.

Evaluation of mccall's quality factors using ahp methodology with numerical example

The Analytic Hierarchy process is a multi-criteria decision making approach, was proposed by Satty from 1977to 1994 [19]. The AHP has attracted the interest of many researchers due to the excellent mathematical properties of the approach. The AHP is a decision support method for solving the complex decision problems. It uses pair-wise comparison of alternatives against the various criteria's using the scale of preference values to construct the judgment matrix. After the construction of judgment matrix eigenvector is required to calculate. Next priority vector can be calculated to find the priority of the alternatives of the problem with respective to various criteria's. Next eigenvalue has to be calculated to find the consistency index, calculate the CI(consistency Index), the formula to calculate the CI is ($CI = (\lambda_{max} - n) / (n-1)$)., using the consistency index consistency ratio is evaluated using the formula CR=CI/RCI, if consistency ratio value <0.1 then the judgment matrix values are consistent, otherwise the judgment matrix values are inconsistent, then the judgment matrix values are reconsidered and CR is evaluated until CR <0 .1.

Table 1. Random Consistency Index (Satty, 2000)

Matrix Size (n)	Random Consistency Index
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45

Table 2. Scale of Relative importance (As per Saaty, 1990)

Weight	Definition	Explanation
1	Equal importance	Two activities in equal importance
3	Moderate importance	One activity moderate over another
5	Strong importance	One activity strong over another
7	Very strong importance	One activity very strong in practice over another
9	Extreme importance	One activity Extreme over another.
2,4,6,8	Intermediate values between two activities	When compromise is needed.
Reciprocals of above non Zero	If activity I has of above non nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with it	

In 19871 and improved its features by Vargas in 2001. It is robust and flexible decision making method for solving the multi criteria problems which are more complex. In this method, initially identify the quality factors Correctness, Reliability, Efficiency, Integrity, Usability of the system and the criteriaEconomical, Technical, Behavioral, Legal are identified as per the organization capability in order to prioritize requirements with respect to feasibility criteria against them. The possible hierarchy made in analytical hierarchy process is pair wise comparison to each other.

The requirement engineer will assign importance on the scale which is from 1 to 9 as per the defined Table 1. The AHP is not only prioritizes requirements but also give the knowledge that to what degree they are more prior. In this method „n" no. of requirements to be compared as n(n-1)/2 pair wise comparisons. During the use of AHP redundancy might take place, therefore consistency ratio must exists in order to know that justifiable prioritization has been achieved.

Algorithm

Step-1: Define the problem, and the objective of the problem.
Step-2: Construct the hierarchical diagram as the main goal at the root level, criteria at the middle level, alternatives at the root level, the entire structure overviews the relationship among the goal, criteria and alternatives.
Step-3: Construct the pair-wise comparison matrices based on criteria i.e. judgment matrix matrix (A).
Step-4: For each judgment matrix calculate eigenvector (n^{th} root value), priority vector P (normalized values of n^{th} root values).
Step-5: Calculate the Eigen value (λ) = (A*P/P) i.e A,P are judgment, priority matrices respectively.
Step-6: Calculate the λ_{max} (i.e. average of all λ values).
Step-7: Calculate Consistency Index, CI= (λ_{max} – n) / (n - 1), where n is the size of matrix.
Step-8: Calculate CR (consistency ratio) =CI/RCI.
Step-9: If consistency ratio<0.1, the judgment matrix values are consistent otherwise judgment matrix values are inconsistent, reconstruct the pair-wise comparison matrix.
Step-10: Construct the criteria's pair wise comparison matrix
Step-11: Calculate the decision matrix to find the final priorities of alternatives

Numerical example

Suppose that the alternatives are Maintainability, Flexibility, Testability, Portability, Reusability, Interoperability of McCall's quality factors. The decision criteria's are Technical, Economical, Legal and Operational. According to the algorithm, step1 to step-9 are evaluated as below. In the Table 1, the consistency ratio is less than 0.1, hence the scale of preference values of McCall quality factors with respect to technical feasibility in the judgment matrix are consistent. In the Table-2, the consistency ratio is less than 0.1, hence the scale of preference values of McCall quality factors with respect to economic feasibility in the judgment matrix are consistent. In the Table 3, the consistency ratio is less than 0.1, hence the scale of preference values of McCall quality factors with respect to legal feasibility in the judgment matrix are consistent. In the Table 4, the consistency ratio is less than 0.1, hence the scale of preference values of McCall's quality factors with respect to operational feasibility in the judgment matrix are consistent. In the Table 5, the consistency ratio is less than 0.1, hence the scale of preference values of feasibility criteria's with respect to feasibility criteria's in the judgment matrix are consistent.

Mathematical Representation

Construct the judgment matrix A

$$A=\begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{pmatrix}$$

$$a_{ij} = 1 \quad \forall \quad i=j,$$
$$a_{ij} = \frac{1}{aji} \quad \forall \quad i \neq j.$$

Calculate the eigenvector=

$$\begin{pmatrix} (a_{11} * a_{11} * \dots * a_{11})^{1/n} \\ (a_{11} * a_{11} * \dots * a_{2n})^{1/n} \\ \dots \\ (a_{n1} * a_{n2} * \dots * a_{nn})^{1/n} \end{pmatrix}$$

Assume that column sum= S

$$P=\begin{bmatrix} P_1 \\ P_2 \\ \dots \\ P_n \end{bmatrix}$$

Where $P_1=[(a_{11} * a_{11} * \dots * a_{11})^{1/n}]/S$,
$P_2=[(a_{11} * a_{11} * \dots * a_{2n})^{1/n}]/S$
$P_n=[(a_{n1} * a_{n2} * \dots * a_{nn})^{1/n}]/S$

Table 1. Construction of Judgment Matrix for Technical feasibility and calculations

	Judgement Matrix (A)						Calculations			
Feasibility Criteria: Technical	Maintainability	Flexibility	Testability	Portability	Reusability	Interoperability	eigen vector	Priority Vector(P)	A*P	eigenvalue(λ)
Maintainability	1	1	2	3	5	6	2.376	0.316	1.980	6.273
Flexibility	1	1	1	3	2	3	1.619	0.215	1.368	6.360
Testability	1/2	1	1	3	5	5	1.830	0.243	1.541	6.342
Portability	1/3	1/3	1/3	1	2	3	0.778	0.103	0.645	6.241
Reusability	1/5	1/2	1/5	1/2	1	7	0.642	0.085	0.621	7.278
Interoperability	1/6	1/3	1/5	1/3	1/7	1	0.284	0.038	0.257	6.811
							7.529	1.000		
									λ max =	6.551
Consistency Index(CI)=			0.11							
Consistency Ratio(CR)=			0.09							
Decision Making =			Judgment Matrix Values are CONSISTENT							

Table 2. Construction of Judgment Matrix for Economic feasibility and calculations

Judgement Matrix (A)							Calculations			
Feasibility Criteria: Economic	Maintainability	Flexibility	Testability	Portability	Reusability	Interoperability	eigen vector	Priority Vector(P)	A*P	eigenvalue(λ)
Maintainability	1	1	3	5	5	6	2.768	0.352	2.295	6.521
Flexibility	1	1	1	2	3	5	1.763	0.224	1.383	6.170
Testability	1/3	1	1	3	5	5	1.710	0.217	1.398	6.430
Portability	1/5	1/2	1/3	1	2	3	0.765	0.097	0.604	6.216
Reusability	1/5	1/3	1/5	1/2	1	7	0.600	0.076	0.546	7.156
Interoperability	1/6	1/5	1/5	1/3	1/7	1	0.261	0.033	0.223	6.730
							7.867	1.000		
									λ max =	6.537
Consistency Index(CI)=			0.11							
Consistency Ratio(CR)=			0.09							
Decision Making =			Judgment Matrix Values are CONSISTENT							

Table 3. Construction of Judgment Matrix for Legal feasibility and calculations

	Judgement Matrix (A)						Calculations			
Feasibility Criteria: Legal	Maintainability	Flexibility	Testability	Portability	Reusability	Interoperability	eigen vector	Priority Vector(P)	A*P	eigenvalue(λ)
Maintainability	1	2	5	7	8	9	4.141	0.457	2.951	6.460
Flexibility	1/2	1	1	3	5	7	1.935	0.214	1.298	6.081
Testability	1/5	1	1	3	5	5	1.570	0.173	1.110	6.408
Portability	1/7	1/3	1/3	1	2	3	0.676	0.075	0.458	6.137
Reusability	1/8	1/5	1/5	1/2	1	7	0.510	0.056	0.406	7.226
Interoperability	1/9	1/7	1/5	1/3	1/7	1	0.231	0.025	0.174	6.843
							9.062	1.000		
									λ max =	6.526
Consistency Index(CI)=			0.11							
Consistency Ratio(CR)=			0.08							
Decision Making =			Judgment Matrix Values are CONSISTENT							

Table 4. Construction of Judgment Matrix for Operational feasibility and calculations

	Judgement Matrix (A)						Calculations			
Feasibility Criteria: Operational	Maintainability	Flexibility	Testability	Portability	Reusability	Interoperability	Eigen vector	Priority Vector(P)	A*P	eigenvalue(λ)
Maintainability	1	1	1	5	7	9	2.608	0.332	2.096	6.324
Flexibility	1	1	1	3	2	3	1.619	0.206	1.326	6.447
Testability	1	1	1	3	5	5	2.054	0.261	1.625	6.228
Portability	1/5	1/3	1/3	1	2	3	0.715	0.091	0.568	6.257
Reusability	1/7	1/2	1/5	1/2	1	7	0.607	0.077	0.561	7.279
Interoperability	1/9	1/3	1/5	1/3	1/7	1	0.266	0.034	0.233	6.888
							7.868	1.000		
									λ max =	6.570
Consistency Index(CI)=			0.11							
Consistency Ratio(CR)=			0.09							
Decision Making =			Judgment Matrix Values are CONSISTENT							

Table 5. Construction of Judgment Matrix for feasibility and calculations

Judgement Matrix (A)					Calculations			
Feasibility Criteria's	Technical	Economical	Legal	Operational	Eigen vector	Priority Vector(P)	A*P	eigenvalue(λ)
Technical	1	1	1	5	1.495	0.331	1.342	4.051
Economical	1	1	1	3	1.316	0.292	1.171	4.016
Legal	1	1	1	3	1.316	0.292	1.171	4.016
Operational	1/5	1/3	1/3	1	0.386	0.086	0.346	4.047
					4.514	1.000		
							λ max =	4.033
Consistency Index(CI)=			0.01					
Consistency Ratio(CR)=			0.01					
Decision Making =			Judgment Matrix Values are CONSISTENT					

Table 6. Calculation of Decision Matrix to find the Priorities of McCall's quality factors

Decision Matrix					
Quality factors	Technical	Economical	Legal	Operational	GOAL
Maintainability	0.105	0.103	0.13	0.028	0.369
Flexibility	0.071	0.065	0.06	0.018	0.216
Testability	0.081	0.063	0.05	0.022	0.217
Portability	0.034	0.028	0.02	0.008	0.092
Reusability	0.028	0.022	0.02	0.007	0.073
Interoperability	0.013	0.010	0.01	0.003	0.033
					1.000

Table 7. Prioritized McCall's quality factors using the significance

Requirement	Requirement Significance	Requirement Priority
Maintainability	0.369	1
Testability	0.217	2
Flexibility	0.243	3
Portability	0.092	4
Reusability	0.073	5
Interoperability	0.033	6

Conclusion and Discussion

A various metrics are exercised for measuring the software product quality prior to implementation. Quality is the main concern when developing the software project/products. The non-functional requirements mainly focus on the quality of products. The objective of this paper is to find the priorities for McCall's quality respect to the quality criteria's technical, economical, legal and operational. The software quality is not possible to view in single window. The quality visualize based on various perspectives of the software stakeholders. The three areas of aspects help us to think about the kinds of tools for improving the software quality. This research paper can motive the extensive research in the requirement prioritization with intent of quality.

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