Quality Focus of Software Layered Technology using Analytic Hierarchy Process : A Case Study

Jogannagari Malla Reddy, Dr. S.V.A.V. Prasad

Abstract- The software engineering is layered technology. The software layered technology consists of process, methods and tools layers to develop the software products. The objective of any software engineering approach is committed towards quality factor. The quality metrics is a key factor in reduction of the gap between academics and practitioners. The various approaches (e.g. Software Factory, CMM, Bootstrap, GQM) have been advocated for the systematic design and introduction of software metrics for improving the process and capability in an organization. The software product quality significance is based on its layers implementation. This evaluation may be difficult to find, which depends on multiple criteria's. The Analytic Hierarchy Process seems to provide an effective approach for properly quantifying the pertinent data. Even though, there are many critical issues that a decision maker needs to be aware. This case study examines some of the practical and computational issues involved when the AHP method used in real time environment to find out the quality significance.

Index Terms— Analytic Hierarchy Process, Alternatives Criteria, Eigine Vector, methods, priorities, process, pairwise comparisons, Priority, Vector, tools.

1 INTRODUCTION

The software development is a difficult task. The development task involves with number of stages such as inception, initial design, detailed design, development and testing and implementation. The software engineering is systematic approach of software development which is concerned with all the aspects of software production. The concept of software engineering includes the Project Planning, Project Tracking, Formal Inspections, Configuration Management, Software Quality Assurance, and Risk Management etc.

The software development has rapid development since last three decades. The software projects are behind schedule and the resulting applications lack of quality. To overcome this problem the software vendors are competitive in developing the quality products at affordable cost within the time frame. The software products may be developed for a particular customer or may be for general purpose. The software product is intangible which consists of programs and associated documentation. There are number of products are available when the market increases, it is becoming more important to device software metrics to quantify the various characteristics of products and its usage. The objective of software metrics are intended to measure the software quality and performance characteristics quantitatively during the planning, construction and execution of software of development

- *Research Scholar, Dept.of Computer Science & Engineering, Lingya's University, Faridabad, Haryana, India, PH-09492479708, . E-mail: jmrsdpt06@gmail.com.*
- *Professor & Dean (R&D), Lingaya's University, Faridabad, Haryana, India , PH-09891528688. E-mail: prasad.svav&gmail.com*

The rigorous research has been conducted on software metrics and their applications. Most of the metrics proposed on the various phases of cycle. The industry does not have standard metrics and measurement practices. Most of the software metric has multiple definitions and ambiguous rules for measuring. However these metrics cannot be applied on the software layered technology in real time environment.

This case study evaluates the significance of quality focus of the product using Analytic Hierarchy process in software layered technology. The decision making process depends on multiple parameters and criteria of layers of software layered technology. The Section 2 explains review of literature of software metrics and Multicriteria decision making system. The section 3 states the various layers in Software Layered Technology. Section 4 describes the Analytic Hierarchy Process in evaluation of quality significance in software layered technology with mathematical derivations. Finally a discussion about future scope and conclusions is given in the Section 5.

2. REVIEW OF LITERATURE

The software quality is the core of software development. Software industry using metrics for quantifying the output of a software project [1]. The Software firms have more challenges to meet the expectations and quality constraints of client requirements. The software vendors use metrics to improve its quality by measuring its capabilities and efficiencies. The measurement is done with the help of Software Quality Metrics. The purpose of software measurement is to quantify all attributes of quality and predict the future quality of software[2]. Software Quality is being gauges by measuring its internal and external attributes [3]. The application of appropriate software metrics at right time helps the software firms to achieve their required and expected products. A number of researchers have worked to address various issues in this domain of quality metrics with using various methods.

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* Sadia Rehman, et al [4] described Software Metrics and its role in global software development with systematic literature review protocol for data search.

* R. Fitzpatrick [5] expressed that the Software quality is the extend to an industry defined set of desirable features are incorporated into a product to increase its performance .

* Dr. Deepshikha Jamwal [6] described various quality models that the " Reliability" is the common attribute in all models(Boehm's Quality model, McCall;s Quality Model, FURPS Quality Model, ISO 9126 Quality Model) . The defined criteria has been defined based on question in order to select the quality model for any organizations that will save the time.

* ISO standards of quality are being adapted by organizations to excel their performance. ISO 9126 quality model have various internal and external quality factors [7].

* Mrinal Singh Rawat, et al [8] focuses on different views on software quality. The paper extend the knowledge to yield the tremendous benefits and betterment in quality and reliability.

* Barbara Kitchenham has held a survey on advancement in software metrics research. The study assesses 103 papers published between 2000 and 2005. She suggested that researchers in software metrics domain need to refine their empirical methodology to solve the quality metric questions [9].

* Kitchenham defined quality as " Quality is a complex concept. Because .the different stakeholders have different views on the quality, it is highly context dependent. There can be no single, simple measure of software quality acceptable to everyone. To quantify or improve software quality in the organization, we must define the quality aspects interested and decide the how to measure them " [10] .

* Software Quality Models assist to control over quality as according to Tom Demcrio " You need not control what you can't measure". The quality measurement is prerequisite to management control in the organization [11].

* Mikael Svahnberg, et al [12] presented the empirical study, that enables quantification of the perceived support software architectures for different quality attributes. This architectures can be created beforehand, but must also be updated to reflect changes in the domain, and enhance the requirements of the software. He investigated a method for identifying a software architecture candidate with respect to quality attributes.

* Thomas L. Saatty [13],[14].[15],[16] described the principles and philosophy of the Multi criteria decision making approach [AHP] in more detail.

* A book was written in 1990 by Nagel and Mills : Multicriteria Methods for Alternative Dispute Resolution (NY:Quorum Books) applying the concepts of quantitative decision making in public administration.

* In 1999, The Ford Motor Company used the AHP to establish priorities for criteria that improve customer satisfaction. Ford gave Expert Choice Inc, an Award for Excellence for helping them achieve greater success with its clients.

* IBM used the process in 1991 for designing its successful mid-range AS 400 computer, IBM won the prestigious Malcolm Baldrige award for Excellence for that effort. Baner et al. (1992) devoted a paper on how AHP was used in bench marking

The literature will help the researchers to estimate quality of the software products, process and firms. The outcomes of this research will useful for any software industry. In order to make the work more reliable, the systematic literature review is way of discovering assessing and inferring all available research relevant to a particular research question or topic area. The researchers have extended their studies on software metrics to improve the quality of product for user satisfaction.

3. SOFTWARE LAYERED TECHNOLOGY

The software engineering is layered technology. It encompasses a process, the management, technical methods, and use of tools to develop the software products. The objective of any software engineering approach is committed for quality factor.

The various philosophies defined in Total Quality Management, Six Sigma, Statistical analytical processes are targeted software development towards improvement of quality culture.

The software layered technology as classified its activities based on importance as quality focus layer, process layer, methods layer and tools layer

Fig. 2. Software Layered Technology

Quality Focus Layer : The bedrock of software engineering

is quality focus. The quality management is backbone of software layered technology which consists of Total Quality Management Tools, Six sigma methods etc. The software product quality should meet its specification. The software product should fulfill the customer quality requirements (i.e efficiency, reliability, etc), developer quality requirements (maintainability, reusability, etc), users (usability, efficiency etc). The quality constraints are non functional requirements. The some of quality requirements are difficult to specify in an unambiguous way. Software specifications are usually incomplete and often inconsistent.

Process Layer : The process layer is the foundation of software engineering ***process*** defines a frame work for timely delivery of software. The key process areas form the basis for management control of software projects. The various tasks can be performed in this layer.

- Determining Deliverables
- Establishing milestones
- Software configuration / Change management.
- Software Quality Assurance

Methods Layer : Software engineering *methods* provide the technical knowledge (i.e " how to's") for building software. Methods comprises various array of tasks of the following .

- Requirement Analysis
- Design
- Program Construction.
- Testing and support.

Tools Layer: The software Engineering *Tools* provide automated or semi-automated support for the process and methods. The tools are used to bring automation in software development process.

Ex : CASE (Computer Aided Software Engineering) and Rational Rose etc.

When the tools are integrated so that information created on tool can be used by another, a system that supports the software development called the Computer aided software Engineering. The CASE tools may also include editors, database, test case generators and code generator which automatically generates the source for the system models.

Software Process Frame work

The process framework consists of process activities which are suitable for all software projects irrespective of its size and complexity. The whole software process framework contains the umbrella activities which exists the set of framework activities embedded with software engineering actions. Each action is highlighted with individual work tasks that accomplish some part of the work implied by the action.

In general vast majority of software projects follow generic process framework Communication, Planning, Modeling, Construction, Deployment and Evaluation .

The generic view of framework describes the number of *umbrella activities* typically as Risk Management, Software Quality Assurance, Formal Technical Review, Configuration Management, Measurement and Work products.

4. ANALYTIC HIERARCHY PROCESS

The Decision making on the basis of several criteria and alternatives is very difficult process. We need a decision method that enables a quantitative comparison between layers based on the quality attributes in software layered technology. Such problem solved with the Analytic Hierarchy Process (AHP). The Analytic Hierarchy Process invented by the ***Saaty*** in 1980 and improved by Vargas in 2001. The AHP was used in multi-criteria decision making and management science by Anderson et al., in 2000. It is a powerful and flexible tool for decision-making in complex multi criteria problems. The solutions can be both objective and subjective. This tool is developed to solve the various issues and derive the solutions.

In this paper the attention is focused on the comparative significance of quality attributes in software layered technology using AHP decision making method.

Structure of AHP method

Analytic hierarchy process is a expert mathematical model which divides the main problem into smaller and more detailed elements.

Decision by AHP method can be divided into three different levels

1. Hierarchy 2. Priorities 3. Consistency

Designing a structured AHP hierarchy means developing a system consisting of a goal of decision making process.

Priorities

After sorting their own set of criteria and the establishment of a hierarchical structure at all levels of assessment, various alternatives or criteria that affect the assessment through verbal explanations and figures are compared. The result is given by the weight in proportion to the scale of alternatives and criterions.

Weight allocation

The correct and responsible determination of the individual sub-scales of assessment criteria is one of the key tasks in solving multi criteria problems. It is therefore necessary to know the solved issues well and know the importance and impact of the criteria used to evaluate the result achieved.

This method allows to gather knowledge about a particular problem., to quantify subjective opinions and to force alternatives in relation to established criteria.

1. Define the problem and the main objectives to make the decision.

2. Build a hierarchical structure as Figure 3, the root node is the objective of the problem, Intermediate level as criteria's and lower levels contain the alternatives. The entire structure overviews the criteria and the alternatives.

3. Construct a set of pair wise comparison matrices.
The element in an upper level is used to compare the elements in the level immediately below with respect to it. For each comparison matrix, find the Eigen value, consistency index CI, consistency ratio CR, and normalized values for each criteria / alternative.

4. Use the priorities obtained from pair wise matrix in the global matrix. The scale for rating characteristics should be established and described in a precise way. Do this for every element. Then for each element in the level below add its weighted values and obtain its overall or global priority. Continue this process of weighting and adding until the final priorities of the alternatives in the bottom most is obtained. The final value is used to make a decision about the objective.

CASE STUDY

We have conducted a case study in **" Vasundhara Software Solutions (P) Limited, Hyderabad"** based on pertinent data, which is collected through questionnaire from various eminent analysts, designers, coders and testers. The other pertinent data is collected from various software libraries.

The following case study is to find the weighted significance of quality attributes in quality focus layer can be evaluated in terms of decision criteria of remaining layers ie. Process, Methods, Tools of the software layered technology. The pair wise comparison matrix represent the corresponding judgment on scale of relative importance.

TABLE 1
SCALE OF RELATIVE IMPORTANCE (As per Saaty1980)

. 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	

The next step in pair wise comparisons, the corresponding maximum left eigenvector is approximated by using geometric means of each row. An evaluation of the eigenvalue method can found in (Triantaphyllou and Mann, 1990). Initially the consistency index(CI) can be estimated. This is done by sum of columns in the judgment matrix and multiply the resulting vector by the vector of priorities (i.e approximated eigenvector) obtained earlier. This result the approximation of the maximum eigenvalue. denoted by λmax. Then, the C.I value measured by using the formula as CI = (λmax-n)/(n-1). Then after the consistency ratio CR is obtained by dividing the CI value by Random Consistency index (RCI) as the table given below.

TABLE 2
RANDOM CONSISTENCY INDEX (Adopted from Saaty)

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

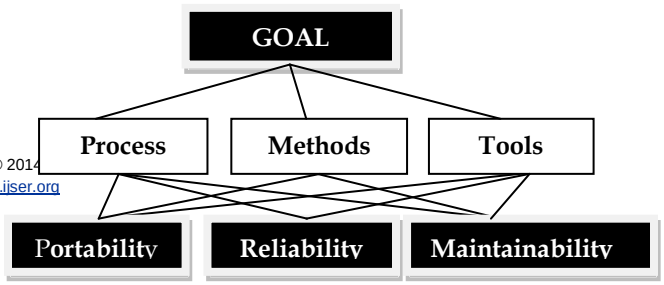
The weights of importance of the criteria are also determined by using pair wise comparisons. If the problem has M alternatives and N criteria, then the decision maker is required to construct N judgment matrices (each criteria) of order M*M and one judgment matrix of order N*N (for N criteria). Finally, the decision matrix and its final priorities denoted as $A^i{}_{AHP}$.

$$A^i{}_{AHP} = \sum_{j=1}^{N} a_{ij}\, w_j, \text{ for } i = 1, 2 \ldots M \quad \text{----} \quad (1)$$

Suppose three quality attributes i.e Portability (P), Reliability (R), Maintainability (M) significance can be evaluated on based on its quality focus, process, methods and tools in the pair wise comparisons and AHP methodology..

The figure.3 shows the hierarchical decomposition of criteria, sub criteria, and alternatives. The Level 0 shows the overall goals of " significance of quality attributes". The next level, namely level 1 shows the criteria of various levels of software layered technology. Its next level namely level 2 is the highest level shows the quality attributes as alternatives.

The weights of alternatives with respect to each of the criteria mentioned in the tables 3 to 5 and the its priority vectors represented in pie graphs from figures 4 to 6.



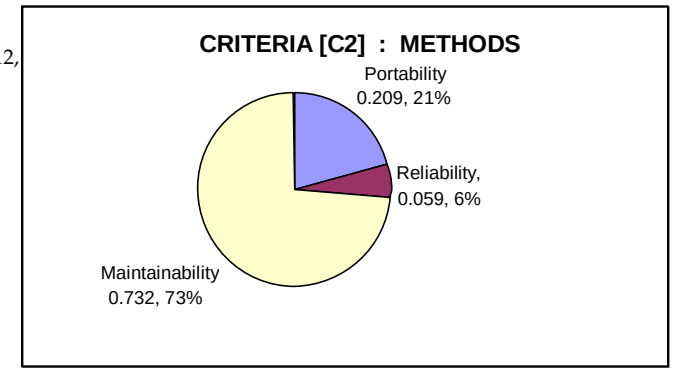


Fig. 3. Hierarchical decomposition of Criteria's & Alternatives

Fig. 5. Weights of alternatives w.r.t Methods

The first table is with respect to the process and ranks of the three quality attributes as follows

TABLE 3
WEIGHTS OF ALTERNATIVES WITH RESPECT TO PROCESS [C1]

PROCESS	P	R	M	Priority Vector
P	1	5	7	0.724
R	1/5	1	3	0.193
M	1/9	1/3	1	0.083
Total Priority				1
λmax. = 3.111,	**CI** = 0.056,		**CR** = 0.096	

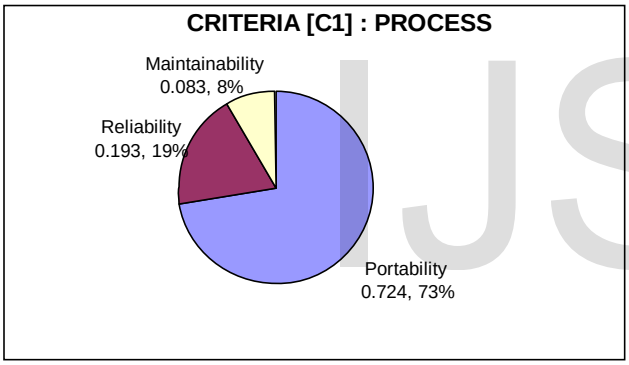


Fig. 4. Weights of alternatives w.r.t Process

TABLE 5
WEIGHTS OF ALTERNATIVES WITH RESPECT TO TOOLS [C3]

Tools	P	R	M	Priority Vector
P	1	5	9	0.730
R	1/5	1	1/3	0.099
M	1/9	3	1	0.171
Total Priority				1
λmax. = 3.618,	**CI** = 0.309,		**CR** = 0.533	

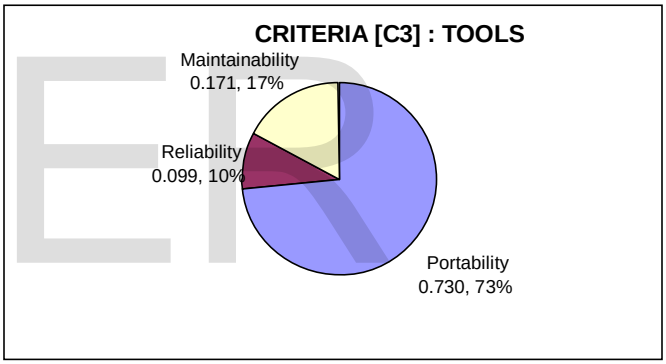


Fig. 6. Weights of alternatives w.r.t Tools

The next two matrices are respectively judgments of the relative merits of portability (P),reliability (R), maintainability (M) with respect to methods and tools of software layered technology

TABLE 4
WEIGHTS OF ALTERNATIVES WITH RESPECT TO METHODS [C2]

Methods	P	R	M	Priority Vector
P	1	7	1/9	0.209
R	1/7	1	1/8	0.059
M	9	8	1	0.732
Total Priority				1
λmax. = 3.969,	**CI** = 0.485,		**CR** = 0.835	

The final step describes the judgment matrix table.6 based on the criteria importance of the three layers of software layered technology.

TABLE 6
WEIGHTS OF LAYERS IN SOFTWARE LAYERED TECHNOLOGY

3- CRITERIA	C1	C2	C3	Priority Vector
C1	1	5	7	0.724
C2	1/5	1	3	0.193
C3	1/7	1/3	1	0.083
Total Priority				1
λmax. = 3.111,	**CI** = 0.056,		**CR** = 0.096	

Figure 7 shows the weights of layers process, methods and Tools layers represented in bar graphs

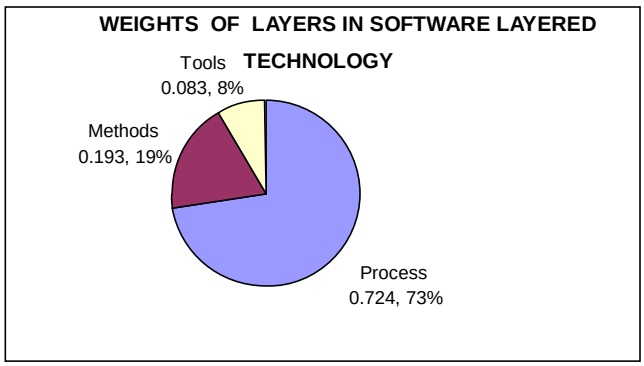


Fig. 7. Weights (Layers of softwar layered)

The previous priority vectors are used to form the entries of the decision matrix for this problem. The decision matrix and the resulted final priorities (ie. Calculated according to formula (1)) as follows

TABLE 7
SIGNIFICANCE OF QULITY FOCUS
IN SOFTWARE LAYERED TECHNOLOGY

Quality Focus	C1	C2	C3	Quality Significance
PORT [P]	0.523	0.040	0.061	0.625
RELIA [R]	0.140	0.011	0.008	0.159
MAINT [M]	0.060	0.141	0.014	0.216
Total Priority				1

The significance of the attributes in quality focus layer shown in the figure. 8 with pie graph is based on performance of remaining layers.

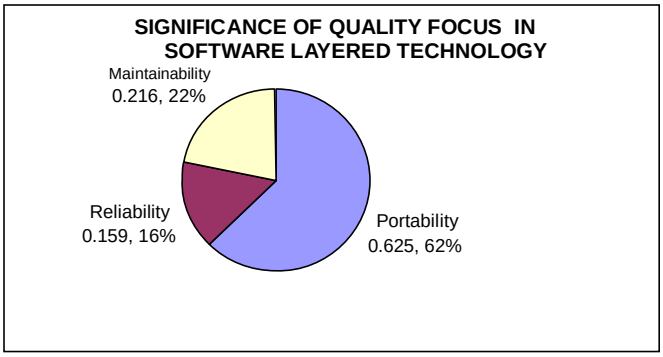


Fig. 8. Significance attributes in Quality Focus of Software Layered Technology

Therefore, the quality significance of the Portability is followed by Maintainability which is followed by Reliability.

5. CONCLUSIONS AND DISCUSSION

The AHP provides a convenient approach for solving complex Multi Criteria Decision Making problems in software engineering. The ***Expert Choice*** (1990) software , which significantly contributed to wide acceptance of AHP methodology. The numerical example in this paper, along with extensive research of authors suggest that when some alternatives to be very close to other, then the decision maker needs to be very cautious. The MCDM method may never end, research in this area of decision making is still critical and valuable in many scientific and software engineering applications.

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