Fuzzy Analytic Network Process (FANP) based Quantification of Component Selection And Ranking For Component Based Software Engineering

A Dissertation

Submitted By

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Under the guidance of

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ABSTRACT

Component Based Software Engineering (CBSE) focuses on using and integrating the pre – existing software components which leads to the development of a new software system. The major challenge in CBSE is to select and rank the component that fits best to the specific requirements of the software to be developed.

Thus, in order to develop a new software using pre-existing component , the components needs to be evaluated and ranked according to their quality attributes Multiple criteria decision making methods help the system developer to select the best fit component that can be used in the system for its development

This thesis proposes a methodology for component selection and ranking based on Fuzzy Analytic Network Process (FANP).This method aims at to build trust on the selected components during the component based development.

CERTIFICATE

This is to certify that **Megha Grover** has completed M. Tech dissertation proposal titled **"Selection and Ranking of a Component from a soft repository using fuzzy Analytical Network Process"** under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the dissertation proposal has ever been submitted for any other degree or diploma.

The dissertation proposal is fit for the submission and the partial fulfillment of the conditions for the award of M. Tech, Computer Science and Engineering.

Date: 07th May, 2015

Signature of Advisor

Mr. Gurpreet Singh

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I would like to take this opportunity to express my deep sense of gratitude to all who helped me directly or indirectly during the making of this dissertation proposal.

Firstly, I would like to thank my mentor, Mr. Gurpreet Singh and Mr Harshpreet Singh for being such a great mentor and best adviser I could ever have. His advice, encouragement and critics are sources of innovative ideas, inspiration and cause behind the successful completion of this dissertation. I am highly obliged to all faculty members of computer science and engineering department for their support and encouragement.

I would like to express my sincere appreciation and gratitude towards my friends for their encouragement, consistent support and invaluable suggestions at the time I needed the most.
I am grateful to my family for their love, support and prayers.

Megha Grover

DECLARATION

I, Megha Grover hereby declare that the dissertation proposal entitled **"Selection and Ranking of a Component from a software repository using fuzzy Analytical Network Process"**, submitted for the M.Tech degree is entirely my original work and all ideas and references have been duly acknowledged. It does not contain any work for the award of any other degree or diploma.

Date: 07th May, 2015

Megha Grover

Reg. No.: 11306808

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Chapter 1

INTRODUCTION

This chapter provides brief introduction about Component based Software Engineering (CBSE) .Various issues in selection and ranking of component are discussed .Brief introduction about Multiple Criteria Decision Analysis (MCDA) approach is given.

1.1 Introduction to Component Based Software Engineering (CBSE)

Component Based Software Engineering is concerned with integrating and maintenance of component based system .It is an important branch of software Engineering which is based on reusable technology to develop the software systems [1]. It defines, implement and compose the loosely coupled independent components into system. It is an easier way to build more functional, efficient and reliable software systems. It is the analysis, design, implementation, testing and management of software systems [2]. The main idea behind CBSE is to reuse already developed components rather than building new components from scratch.

CBSE came into existence from the failure of object oriented development to support reuse of components more effectively because objects are specific and components are abstract in nature as compared to object and classes and components can be considered as a stand –alone service providers.

CBSE process is same as that of other engineering practices .The only difference is that it (CBSE) uses already existing components to develop the system rather than developing new component from scratch. It utilizes the component repository to select components. Components are selected evaluated and adapted according to the requirements [3], for building the system. Some modifications are also made to build new system .Components are integrated to the system and then compatibility and integration testing is done [4].

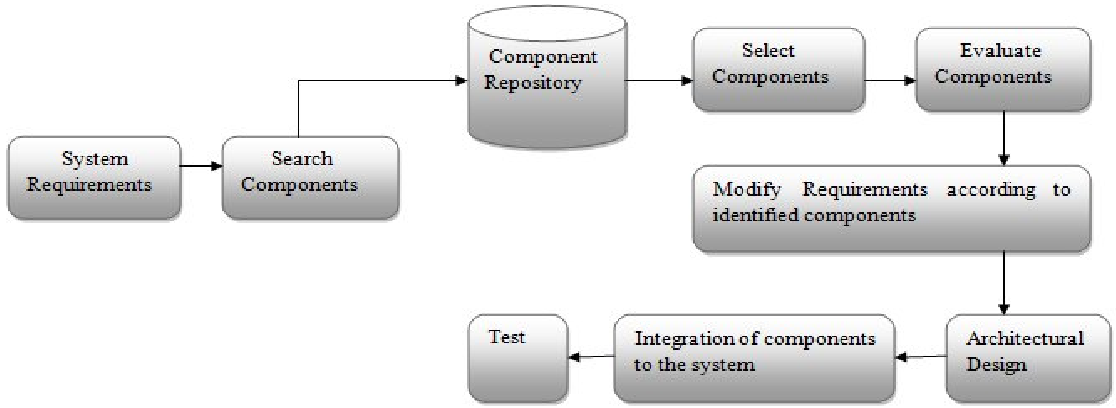

Fig 1.1: CBSE Process

1.1.1 SOFTWARE COMPONENT

A software Component is a software element that conforms to component model and can be independently deployed and composed without any modification. It is an independent executable entity and there is no need to compile it before, when it is to be used with other component systems. It can be software package, web service, web resource or any module. In OOPS components are considered as 'object' or 'classes'. Components interact with each other through interfaces [5].

Components are stored in 'Component Repository' and retrieved from it whenever and whichever required. Validated components selected from software repository are used only in developing the software systems. Process and hence decreasing the market time

There are two types of components:

1. **Commercial Off the Shelf (COTS) Components**: It is also known as 'Black Box Components'. These Components are commercially available in the market. These components are available in the market to buy and use. These may be pre –built components from a 3rd party vendor or in house components.
2. **Green Field Components:** Because there are no relevant component is available for use or reuse so software system needs to be develop from new components.

1.1.2 Advantages of COTS Components

Various advantages of COTS components are [6, 2].

1. **Reduced Marketing Time**: Reusability of pre-existing components fastens the completion and hence reduces the time to market.
2. **Increased Reliability**: COTS components are more tested and used by many people and hence more reliable as compared to other components.
3. **Increased Flexibility**: Users can change suppliers for better priced products.
4. **High Degree of Consistency**: Validity of COTS Components leads to the consistency in the system.
5. **Reduced Development Time**: Since COTS components are easily available in market so there is no need to waste time in building the components from scratch.
6. **More maintainable:** COTS components are more maintainable as system documentation is provided with the application.

1.2 COMPONENT SELECTION PROCESS.

Component selection process is a process of choosing a subset of components that satisfies required functionalities and then integrates them into the software system. Component Selection process in CBSE is shown in Figure 1.2

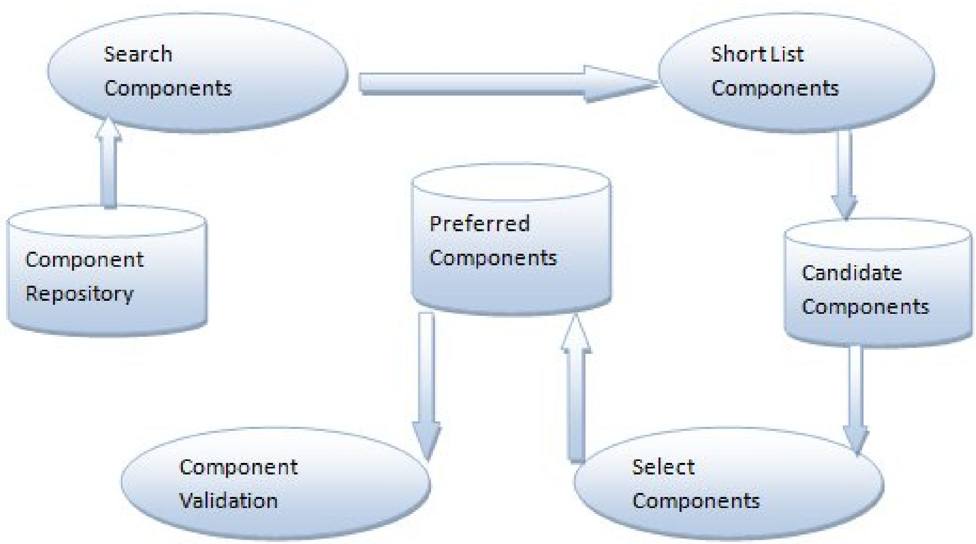

Fig 1.2: Component Selection Process

1.3 Challenges in Component Selection

Issues in component selection process are as follows [6, 7]:

1. **Trust**: It is very difficult to trust the components (Black-box) components as no source code of such components are available with them.
2. **Validation:** The detailed specification of component is required in design phase but component validation is hardly carried out.
3. **Complex criteria Selection**: It is very difficult to choose desired and reliable component from a software repository.
4. **Increased number of options (alternatives):** With increase number of components it becomes very difficult to select the best-fit components from number of alternatives.
5. **Multiple Criteria Problem:** Component selection is a multiple criteria problem involves conflicting requirements and different components having different scores on different criteria.
6. **Complex Criteria Problem:** Criteria selection becomes very large in very large and complex project
   - **Interface Incompatibility:** Interface can e compatible with one another. It may be of any type:
   - **Operation incompatibility:** Such type of incompatibility occurs when names of operations in composed interfaces are different.
   - **Parameter incompatibility:** Such type of incompatibility occurs on different operation types.

1.4 Component Selection Problem as a Multiple Criteria Problem

The major issues in CBSE Is to trust the selected component for building a system as no source code is available of COTS components and due to risks associated with the third party vendor.

Component selection process is a multiple criteria problem as to choose a component from various alternative components which fits better than others. A component needs to be selected on multiple objectives or criteria for which various alternative components are available. In component selection process there may be need of making large decisions of same kind [7].The process may require various decision makers, participant's .

1.5 Multiple Criteria Decision Analysis

Multiple criteria decision analysis (MCDA) is an approach to solve multiple criteria problems .It is well known branch of decision making. It is sub discipline of operation research that considers multiple criteria for decision making. It is a valuable tool that can be applied to many complex decisions In a multiple criteria problem, various alternatives are present for the solution of the problem but having different scores on different objectives [8].It builds the confidence in various decision process [9] In this process criteria are identified for selection and weights are assigned to each criteria to show the relative importance of each criterion. This process has four basic steps:

1. Development of relevant criteria
2. Identify possible courses of action
3. Formal evaluation of each course of action
4. Formulation of priorities

1.5.1 Key Features of MCDA

Performance Matrix

The standard feature of MCDA is Performance Matrix in which each row describes an option (alternatives) and each column describes the alternatives against each criterion.

Scoring and Weighting

Scoring: In this, each alternative is assigned a weight randomly on strength of a preference scale for each option for each criterion.

Weighting: Numerical weights are assigned to define, for each criterion.

1.5.2 Advantages of MCDA

Various advantages of MCDA are as follows:

1. It provides audit trial as score and weights are used.
2. It is open and explicit.
3. The choice of objective and criteria are open to analysis.
4. It can provide an important means of communication, within the decision making body.

1.5.3 MCDA Methods

Various MCDA techniques include AHP, ANP, FANP, Utility theory, WSM, PROMETHEE-GA1A etc .All these are solving the multiple criteria problem, such that each method has its own merits and demerits. Application of these methods is depend on the situation and complexity of decision making process. Steps used by MCDA methods are explained below as [2]:

1. Define the problem to be solved.
2. Identify the available options.
3. Identify the criteria for the evaluation of alternatives.
4. Assign weight to each option against each criterion.
5. Assign weight to each criterion according to its importance.
6. Calculate overall weight of an alternative.
7. Analyze the results.
8. If necessary perform the sensitivity analysis
9. Choose the value which scores high.

i. Analytic Hierarchy process (AHP)

It is a method for ranking decision alternatives and selecting the best one when decision maker has multiple criteria. It gives answers to questions such as which one? With AHP decision maker selects the best alternative that meets the objective, by developing the numerical score to rank each decision alternative, preferences between alternatives are determined by making pair wise comparisons. Comparisons between alternatives are made using preference scale (1-9) which lies between equal importances's to extreme importance.

Steps used by AHP are as follows [2, 10]:

1. Make an evaluation matrix by placing the score or weight of each alternative. Value of 'a_{ji}' is filled with the reciprocal value of 'a_{ij}'.
2. Compute the sum of all columns of evaluation matrix.
3. Divide each element of evaluation matrix with its respective column sum.
4. Compute principle Eigen vectors by taking average of all the values across rows.
5. Eigen vector indicates the relative weight of each alternative.
6. If necessary compute the consistency check.

Advantages:

1. It is less time consuming.
2. Very easy to use and understand.
3. It allows consistencies and cross checking between the different pair wise comparisons.

Disadvantages:

1. Allow some inconsistencies in results because it becomes erroneous to compute Eigen vectors for large no of alternatives.
2. Input to the evaluation matrix is restricted to only ordinal and interval scale.

ii. Weighted Scoring Method (WSM)

In this method, weight is assigned to each criterion which indicates its relative importance Scores are assigned to each option against each criterion which indicates their performance on that criterion [2].Final score indicates the overall performance of options with respect to each other. Steps used in WSM are as follows [10, 2]:

1. Identify the problem
2. Identify the criteria.
3. Assign the weight to each criterion to indicate its relative importance.
4. Score the alternatives which indicate how each component alternatives performs against each criterion.
5. Compute the weighted scores. Score of each alternative is multiplied by its corresponding weight and then add the same of all alternatives against the particular criterion
6. If necessary perform the robustness analysis of results.

Advantages:

1. It is very simple to use.
2. It can be used for real time problems or scenarios.

Disadvantages:

1. Limited Scope
2. Unit of all criteria should be same.

III. Analytical Network Process (ANP)

Analytic Network process is a general form of AHP .It is used in multi criteria decision analysis for making a suitable decision in order to solve the problem.ANP Steps can be summarized as follows

1. The problem is divided into sub network of problems as depicted below in fig 1.3

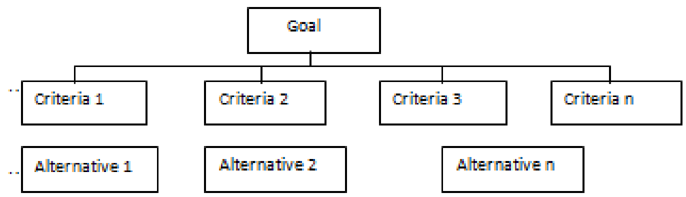

Fig 1.3: Network structure of elements

2. The qualitative scale which is presented by Saaty is as follows: (the equal importance indicates similarity to objective),moderately important (one action is somewhat good as compared to other one),reasonable, plus strong weight (one action is powerfully good than other one),strong plus , very well-built confirmed important , very ,very strong and excessive importance are given.

1	Equal importance
3	Moderate importance of one above another
5	Strong or essential importance
7	Very Strong or demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate importance

Table 1: Fundamental Scale for judgment

3. In third step pair wise comparison is made between different criteria's. The criteria in the "i" row is compared with the criteria in the "j" column. If the criteria of "I" row is superior to the "j" column then it is written as (i, j) and (j, i) is the reciprocal of (i, j)

		C1	C2	C3	C4	Am
	C1	C2	C3	C4	Am	A1m
C1	1	C12	C13	C14	A1m	A2m
C2	C21	1	C23	C24	A2m	A3m
C3	C31	C32	1	C34	A3m	A4m
C4	C41	C42	C43	1	A4m	

Fig 1.4: Super Matrix

4. Relative importance is calculated by finding Eigen value and related Eigen vector of the comparison matrix .The elements are normalized and are termed as weight of criteria and sub criteria.

	C1	C2	C3	C4
C1				
C2				
C3				
C4				
Total				

	C1	C2	C3	C4	Sum/mean	Normalized
					→	
					→	
					→	
					→	

Fig 1.5: Normalization Process

5. A super matrix is obtained by combining the entire matrix in whole i.e. performing pair wise comparison between every criteria and alternative with one another. If the sum of all columns are equal to one then it is called as weighted super matrix and if column sum is less than or not equal to one then it is called as unweighted super matrix The matrix is normalized till its column values become equal to or less than one.

		Criteria					Alternatives			
		C1	C2	C3	C4	C5	A1	A2	A3	A4
Criteria	C1						V_{A1m}			
	C2						V_{A2m}			
	C3						V_{A3m}			
	C4						V_{A4m}			
	C5						V_{A5m}			
Alternatives	A1	V_{A1m}	V_{A1m}							
	A2	V_{A2m}	V_{A2m}							
	A3	V_{A3m}	V_{A3m}							
	A4	V_{A4m}	V_{A4m}							

Fig 1.6: Weighted Super matrix

6. Convert the weighted super matrix to the limit matrix.
7. .Decide the most appropriate alternative from the limit matrix.

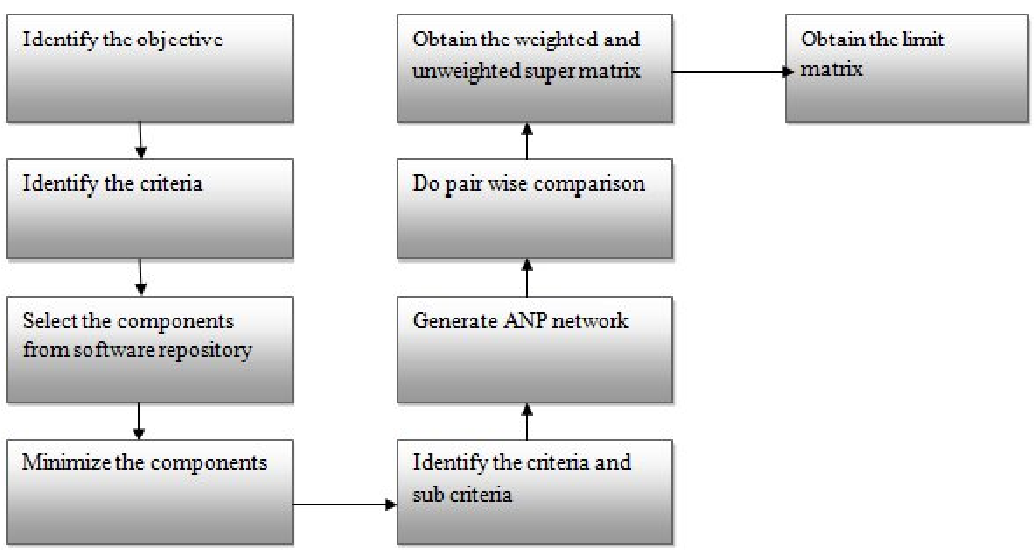

Fig 1.7: Steps involved in ANP Process

iv. Fuzzy Theory

It is an extension of classical set theory that allows solving a lot of problems related to the dealing with imprecise and uncertain data. It takes into account the insufficient information. In 1965 Zadeh proposed the fuzzy theory for the problems in which judgments, observations are vague and imprecise .Fuzzy logic refers to many valued logic that deals with approximate reasoning .It is mathematical logics that attempts to solve problem by assigning values to imprecise spectrum of data in order to arrive at the most accurate conclusion possible. Generally Fuzzy set is defined by membership function, which represents grade of any element x of X that have partial membership to M [11]. Zadeh proposed to use values ranging from 0 to 1 for showing membership of objects in fuzzy set [11].

Triangular fuzzy number: Triangular fuzzy number is represented by three points or parameters (l, m, u) .l represents the smallest possible value, m represents the most promising value and u represents the largest possible value .Each triangular fuzzy number has linear representation on its left side and right side such that its membership function can be defined as

$$\mu_{\tilde{F}}(x)=\begin{cases}(x-l)/(m-l), & l\le x\le m\\(u-x)/(u-m), & m\le x\le u\\0, & otherwise\end{cases}$$

v. Fuzzy Analytic Network Process

Conventional AHP/ANP method is inefficient in dealing with fuzzy or imprecise judgement during pair wise comparison process. Although scale (1-9) provides judgement but it is not very accurate method of judgement. Thus, in order to solve real life problems and to provide best solution, or result, it is advised to make project selection under fuzzy conditions.

Steps of Fuzzy Analytic Network Process

1. Identify goal, criteria, sub criteria, alternatives and clusters to be used in the proposed model.
2. Structure the problem into network including alternatives, criteria’s, sub criteria’s, clusters and dependencies between them.

3. Construct a Pair wise of the components with fuzzy judgments. Pair wise comparison matrices are formed by the experts by applying fuzzy scale given in table 2.

Linguistic Term	Fuzzy Number	TFN(1 ,m ,u)
Extreme importance	9^{-1}	1/9,1/9,1/9
Very importance	7^{-1}	1/8,1/7,1/6
Essential Unimportance	5^{-1}	1/6,1/5,1/4
Moderate Unimportance	3^{-1}	1/4,1/3,1/2
Equally Importance	1	1,1,1
Moderate Importance	3	2,3,4
Essential Importance	5	4,5,6
Very Vital Importance	7	6,7,8
Extreme Importance	9	9,9,9

Table 2: Table of linguistic scales

4. Constructing the fuzzy comparison matrix by using triangular fuzzy numbers triangular fuzzy number is defined by three parameters (l, m, u) .l parameter denotes the smallest possible value, m denotes the most promising value and u denotes the largest possible value.
5. Construct an initial super matrix: Super matrix is formed by doing pair wise comparisons between different criteria's The criteria in the "i" row are compared with the criteria in the "j" column in the form of (I, j) .If the criteria of "i" row are superior to "j" column, then it is written as (i, j) and (j, i) is the reciprocal of (i ,j).
6. Obtain the weighted super matrix: Weighted super matrix is the one in which all the column sum are equals to one. It is obtained by multiplying the unweighted super matrix by the corresponding cluster priorities.
7. Calculate the limit super matrix: Limit the weighted super matrix by raising it to sufficiently large power so that it converges into stable super matrix
8. Rank the alternatives by comparing it with the values given in the table 2.

vi. Simple Multi-Attribute Rating Technique (SMART)

This technique is very efficient and simple Multiple Criteria Decision Analysis approach. It is not based on pair wise comparisons of alternatives. Value Functions are used to rate the alternatives [12]. Non linear functions can also be used according to the situation.

Following are the steps used in SMART are [13]:

1. Choose the objectives.
2. Choose the alternatives
3. Choose the weight of each objective
4. Score the alternatives against each criterion.
5. Rank the alternatives. Score i=sum of all ‘j’ of ‘W_jS_{ij}’ where ‘i’ represents the alternative and ‘j’ represents the criterion. ’Wj ‘represents the weight of the criterion ‘j’ and ‘S_{ij}’ represents the score of alternative’ i’ on criterion ‘j’.
6. If necessary, perform the sensitivity analysis.

Advantages:

1. In SMART technique, rating of alternatives is not relative and thus the change in number of alternatives will not affect the individual scores of alternatives.

Disadvantages:

1. It cannot be used in multiple situations as compared to other MCDA methods.

vii. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) and Geometrical Analysis of Interactive Aid (GAIA).

PROMETHEE is a multiple criteria decision making analysis method. It is an outranking method, based on pair wise comparison of alternatives. Steps for solving multi criteria problem with this problem are:

1. Determine the alternatives to solve the problem.
2. Determine the evaluation criteria.
3. State the problem.
4. Create an evaluation table or (n*k) matrix with ‘n rows’ (number of alternatives) and ‘k’ columns (number of evaluation criteria) and place the score value of each alternative based on each criterion.
5. Assign the weight to each criterion.

6. Find the difference between each pair of alternatives based on each criterion.
7. Find the preference of the one alternative over the other as a function of difference between each pair of alternatives based on each criterion.
8. Calculate the degree of preference.
9. Calculate the positive and negative outranking flow of each option and then compute the net outranking flow of the option. Value greater than 'zero' indicates that the given option has outranked the other options and value lower than 'zero' indicates that the option is outranked by the other options on all criteria.
10. Obtain the outrank flow of each option on each criterion.
11. Obtain the profile of an alternative on all the criteria.
12. Select the alternative which has highest profile.

1.6. Quality Attributes for the Selection of Components

Software Quality is a measure of how successful is the software in meeting the needs and requirements of the users. It consists of software quality assurance, software quality control and other quality aspects [14]. Different quality models such as McCall Model, Boehm's Model, ISO/IEC 9126-1; ISO/IEC 25010:2011 and FURPS Model have been proposed that can be used as a base to define a commonly agreeable quality framework. All these approaches have generally categorized quality attributes into three categories [15]

1. **Product Operation:** Expected quality attributes in the product operation are correctness, efficiency, usability and integrity.
2. **Product Revision**: Expected quality attributes in product revision are maintainability, testability, flexibility.
3. **Product Transition**: Expected quality attributes in product transition are portability, interoperability and usability. In our proposed method ISO/IEC 9126 has been used for defining the criteria. It describes software product quality in terms of external quality, internal quality in use [15].

Characteristics	Sub characteristics
Functionality	Suitability Accuracy Interoperability Security Function Compliance
Reliability	Maturity Fault Tolerance Recoverability Reliability Compliance
Usability	Understandability Learn ability Operability Attractiveness Usability Compliance
Efficiency	Time behavior Resource Utilization Efficiency Compliance
Maintainability	Analyzability Changeability Stability Testability

Table 3: ISO/IEC 9126 -1 Model

1.7 Challenges in Component Based Software Engineering (CBSE)

Various challenges in CBSE are as follows:

1. Certification of components and developers become difficult as more components become available from more and more vendors.
2. It demands new personnel at both the technical and the managerial levels.
3. The components must sufficiently general to cover the different aspects of their use and at the same time they must be concrete and simple enough to serve a specific and particular requirement in an efficient way.
4. Limited research is available on component selection, classification and retrieval.
5. The main challenge in this domain is to achieve a best conversion procedure from requirements to components and from components to the system.

1.8 Thesis Organization

Chapter 2: Describes the literature review about various component selection approaches.

Chapter 3: Describes the scope of proposed work, formulation of the research problem, the objectives to achieve and the research methodology used to achieve the objectives.

Chapter 4: Describes the results of the implementation to justify the achievement of the stated objectives.

Chapter 5: Concludes the work presented in the thesis followed by the future scope of the proposed

CHAPTER 2

LITERATURE REVIEW

CBSE plays an important role in efficient and fast development of software systems as compared to other engineering practices. Various techniques help us in the evaluation and selection and ranking of software components such as AHP, ANP, SMART, WSM, Utility Theory etc. This chapter includes some literature review about CBSE and some methods to solve the issues of selecting and ranking the suitable components and to build the trust on the selected components.

Shah Nazir et al in [15] (2014): Proposed ANP method for selection of COTS components from the software repository. Following are the steps used in ANP are:

Step 1: The problem is divided into sub network of problems.

Step 2: The qualitative scale which is presented by Saaty is as follows: (the equal importance indicates similarity to objective),moderately important (one action is somewhat good as compared to other one),reasonable, plus strong weight (one action is powerfully good than other one),strong plus , very well-built confirmed important , very ,very strong and excessive importance are given.

Step 3: In third step pair wise comparison is made between different criteria's. The criteria in the "i" row is compared with the criteria in the "j" column. If the criteria of "I" row is superior to the "j" column then it is written as (i, j) and (j, i) is the reciprocal of (i, j)

Step 4:.Relative importance is calculated by finding Eigen value and related Eigen vector of the comparison matrix .The elements are normalized and are termed as weight of criteria and sub criteria.

Step 5.A super matrix is obtained by combining the entire matrix in whole i.e. performing pair wise comparison between every criteria and alternative with one another. If the sum of all columns are equal to one then it is called as weighted super matrix and if column sum is less than or not equal to one then it is called as unweighted super matrix The matrix is normalized till its column values become equal to or less than one.

Step 6: Convert the weighted super matrix to the limit matrix.

Step 7: Decide the most appropriate alternative from the limit matrix.

ISO/IEC 25010:2011 quality model attribute has been used for selecting components, which categorize the quality attributes in the three categories:

i. **Product Operation**: Efficiency, Usability and integrity are the expected quality attributes in product operation.

ii. **Product Revision**: Maintainability, flexibility, adaptability are the expected quality attributes in product revision.

iii. **Product Transition**: Portability, Reusability, interoperability are the expected quality attributes in product transition.

K.Kaur, H.Singh in [16] (2014) : has shown the application of PROMETHEE in evaluating ,analyzing and selecting the appropriate COTS components to meet the requirements of the users and organization .This paper also discusses the benefits of using PROMETHEE over other multi criteria decision analysis method(MCDA).PROMETHEE is a multi criteria method. It can be applied in various kinds of fields such as banking and industrial location. It makes the selection of COTS components easier. Following are the steps of the stated method:

1. Determine available alternatives.
2. Determine the evaluation criteria.
3. Define the problem statement.
4. Create an evaluation table (n*k) matrix with n as number of rows and as an alternatives and k as number of columns as evaluation criteria.
5. Assign weight to each criterion
6. Find the difference between each criterion
7. Find the preference of one alternative over other alternative.
8. Calculate the degree of preference
9. Calculate the positive and negative ranking of each option.
10. Obtain the outrank flow of each option.
11. Obtain the profile of an alternative on each criterion.

T. Partani, S. V. Marashi & M. Haji Alishahi [17] (2013): Proposed a fuzzy analytical network process in SWOT (strength, weakness, opportunities and threat) which is one of the most famous table technique in strategic planning process in identifying strategic factors of organization and by discovering and identifying those factors, organization can build strategies which are referred to as SO (Strength and opportunities), ST (Strength and Threat), WO (Weakness and Opportunities),WT (Weakness and Threat). Internal dependencies are taken into account by making use of fuzzy logic. In this study fuzzy method used was Chang's extent analysis method. FANP helps the planners to model the SWOT analysis for the organization. Research results have shown that when dependency exists among various SWOT factors, then this dependence could change the weight and priority of strategy alternative.

Becker, C.et al. in [7] (2013): Presented a tool and method for cross referencing the criteria across cases and set of impact factors helps in identifying the criteria. Various challenges have been discussed like (i) unclear specification of the criteria (ii) criteria identification is complex task (iii).some performance evaluation oriented tasks requires great efforts and time. Decision support system (DSS) helps to address these challenges by considering the impact factor of particular criterion. Various metrics have been proposed in this paper that can be used to define the impact factors like significance coverage, selectivity of criteria

Ibrahim H. et al. in [18] (2011): State that by using COTS Components in the software development process provides various advantages as to reduce time, cost and effort and thus improves reliability and provide high level of functionality .This study also states THE uncertainty in black box nature of COTS components .This paper gives an overview of COTS selection methods: AHP, OSTO, COTS Acquisition Process (CAP), Comparative Evaluation Process (CEP), Plan, Establish, Collect and analyze. Uncertainty Handling in COTS selection method have been proposed .This method is based on AHP to rank the components and Bayesian Belief Network (BBN) to represent the uncertainty. It is based on 5 steps

1. Identify the user requirements and COTS components

2. Refine the criteria.

3. Filter components against criteria in order to obtain the correct solution

4. Evaluate the components using the AHP.

5. Obtain the final results

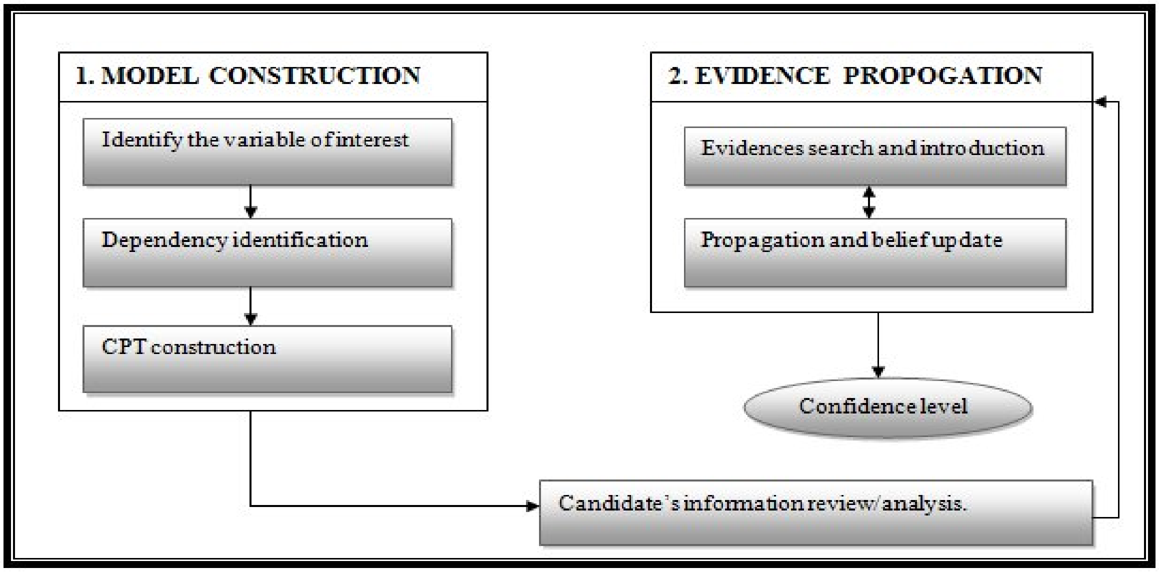

Fig 2.1: Bayesian Belief Network

Bakshi .T.et.al.in [19] (2011) : Proposed a method “Additive Ratio Assessment “ for the selection of projects on the basis of MCDA approach .AHP is used for assessment for the selection of projects ,for defining the criteria and for the evaluation of the project It uses ARAS for final ranking of projects among alternatives .

Following are the steps used by Additive Ratio Assessment:

1. Create Evaluation matrix.

2. Create Normalized matrix.

3. Criteria are determined by the AHP method.

4. Obtained the weighted normalized matrix.

Kaur, A.et al. in [3] (2010): Presents an approach for evaluation criteria of reusable software components**.**. This paper states the component selection problem as simple and criteria based problem. Pareto Dominance Principle, an evolutionary approach is used for component selection. This paper also provides an overview of the off The Shelf Option (OSTO) method for defining evaluation criteria; for analyzing evaluation results and performing cost benefit analysis. It helps in selecting components; performing cost-benefit analysis. Various categories of evaluation criteria has been discussed (i) Product quality requirements (ii) functional requirements (iii) architecture and domain compatibility (iv) various strategic concerns like future plans, cost, time and effort.

Tanhaei, ,M. et al .in [20] (2010): Presented a component selection method for the construction of Software Product Line (SPL) based on architecture .In SPL components are selected by taking cost and benefits into consideration. A proper architecture should be used for constructing SPL .It provides abstraction to the component .Components are selected on the basis of product line requirements that are further prioritized on the basis of benefits, importance etc. If requirements vary then additional components are plugged in to fulfill the requirements and if the requirements are same, common components can be used to develop the system. The components are evaluated on the basis of quality and non-quality attributes. Knowledge based is used for checking any confliction in requirements.

Ismail, S.et al. in [21] (2008): Provides an overview of CBSE, its benefits and challenges .In this paper Component evaluation approaches have been categorized into four categories:

Product Line Engineering Components (PLC): seven criteria like under stability, functional communality; non functional common ability; variability richness and tailor ability; replace ability are considered under PLC .semi-formal or formal technique are used to define metrics .Level of validation is very low

Quality Components (QC): reliability, efficiency, maintainability, portability criteria's are considered for quality components. Informal or wish-list techniques are use to define the metrics. Level of validation is very limited.

Reusable Components (RC): portability, flexibility, probability, under stability are considered for reusable components. Informal or semi- formal technique is used to define the metrics.

Originality Components (OC) : Functionality ,usability, efficiency , reliability and maintainability are considered for original components .Informal techniques are used to define the metrics .Level of validation is low but more than PLC.

Vescan, A., G.et al in [22] (2008): Presented an evolutionary algorithm for the purpose of software component selection process .It gives an overview of the related work done in the process of software component selection. It introduces two evolutionary approaches: Requirements based chromosome representation and component based chromosome representation. Requirement based Chromosome representation has two objectives (i) to minimize the components (ii) to minimize the total cost of the components whereas Component based chromosome representation focuses on (i) to minimize the remaining requirements (ii) to minimize the number of the components to be used (iii) to minimize the cost of the components. It also considers the dependencies between the system requirements that are to be satisfied by the target software system.

Alexandre Alvaro, Rikard Land, and Ivica Crnkovic in [23] (2007): Focuses on the need to evaluate the components. This paper includes the main activities of component evaluation: (i) Component selection (which is selected by decision makers using various MCDA approaches), (ii) Component Certification, in order to increase the trust on component. This study examines This paper examines the primary or basic similarities and difference between these two types of component evaluation and it also demonstrates how these two method of component evaluation fits in the overall process view of component –based development (CBSD) for both software product line development and COTS based development.

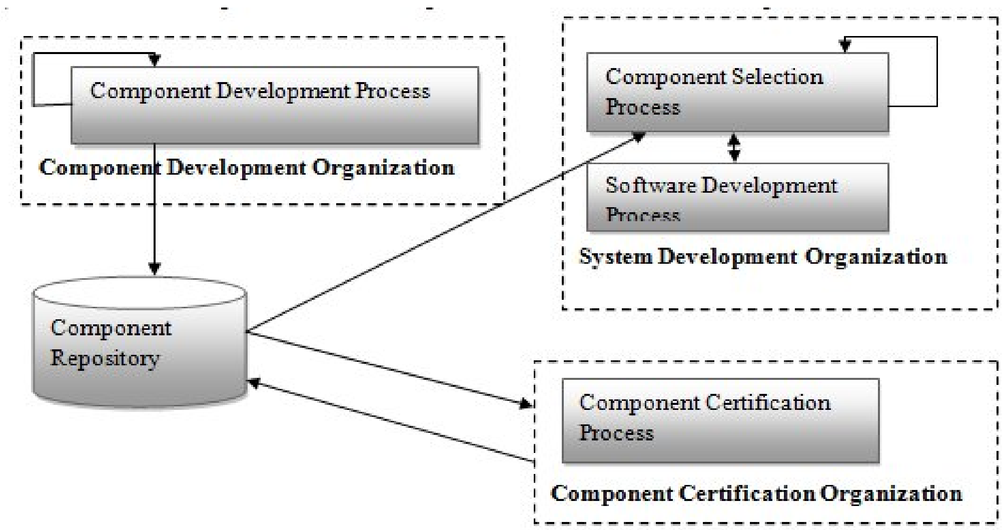

Fig 2.2: The main organization and life cycle processes related to component evaluation

Hutchinson.J. et al. in [2] (2006) : Gives an overview of the CBSE process .It is told that COTS components provides various kinds of advantages so as to reduce development time, improve reliability and flexibility . It also addresses the various risks and challenges associated with the requirement change, supplier and performance risks of third party components, difficulty in mapping the requirements to the components with no source code available with them, lack of tool support in reusable technology .Various decision analysis approaches can be used to address these challenges .For negotiation techniques various models can be used as Barter/Bargaining Model, Request for quotes and auctions. It is told that various MCDA methods can be used in component selection and evaluation in Component Based Development (CBD) like AHP, SMART, WSM and Utility Theory.

Thomas L.Saaty in [25] (2006): Explained about Analytic Network Process with simple example. It is simple process that provides a framework for decision making without making any assumption about the independence of the elements within a level and the independence of higher elements from the lower level elements. ANP consist of two parts (i) the first consist of hierarchy or network of criteria and sub criteria. (ii) Network of influences among the elements and clusters. The network varies for each criterion and super matrix will be different for each criterion. This paper provides some fundamental ideas about ANP are:

1. ANP is built on AHP.
2. ANP deals with inner dependence (dependence within set of elements) and outer dependence (among different set of elements).
3. ANP not just prioritize elements but also group of clusters and elements.
4. ANP is a non linear structure that deals with source, cycles and sinks.
5. The loose network structure of ANP makes the representation of elements easier without concern for what comes first and what comes next in hierarchy.

Grau, G.et al. in [24] (2004): Presented a technique named as description, evaluation and selection of COTS components (DesCOTS) which is used to select the COTS components on the basis Of functional and non-functional requirements .This paper proposed the COTS requirement engineer as a basis of component evaluation. In evaluation tools, components can be added, modified or removed on the basis of quality attributes derived from quality model defined by domain expert. Priorities are set to different requirements by the requirement engineer and COTS are selected on the basis of those requirements.

It also states that the quality model based on Strategic Dependency (SD) model is time consuming There are 4 types of actors participating in Strategic Dependency model used by DesCOTS : (i) Domain Expert :Defines quality model to evaluate components (ii) End organization (iii) Requirement Engineer (iv) Component supplier ..DesCOTS can be used in distributed environment like ERP, Client-Server Systems, Application and mail server

Carvallo, J.P.et al .in [4] (2006): Stated that during the selection of COTS Components there needs to be take care of both the technical and non-technical aspects .ISO/IEC 9126 model takes into account both the internal and external quality model and quality in use. This standard includes portability, maintainability, efficiency, usability, reliability and functionality. Three catalogues are compared in the paper :

1. **NT –ISO/IEC**
2. **Extended NT –ISO/IEC**
3. **Customized NT-ISO/IEC**

   Non-Technical requirements are divided into 3 categories as mentioned in Table

Supplier	1.Structure of organization 2.Market position of organization 3.Reputation and certification 4.Services offered by suppliers
Business	1.Licensing option 2.Warranty provided 3.Cost of licensing 4.Cost of implementation 5.Cost of networking facilities 6 Proprietary rights 7.Cost for platform establishment
Product	1.Product history 2.Outcomes and deliverables 3.Customization and parameterization

Table 2.1: Non Technical Requirements

P.Botella, et al in [14] (2004): Focused on the concepts of ISO/IEC 9126 Model that needs refinement. Paper is divided into three sections (i) Focuses on the hierarchal form of quality entities (characteristics, sub characteristics and attributes) (ii) Proposed criteria to distinguish between attributes and sub characteristics, distinguish between basic attributes and derive attributes (iii) distinguish different categorization criteria of metrics (scale, type, objectivity ,qualitative and quantitative).UML diagrams has been shown to represent the concepts of their standards and relationships and it also underline the need for having tool support for quality model development and metrics definition.

CHAPTER3
PRESENT WORK

CBSE provides various advantages in the field of software development .But still there are many issues that need to be handled carefully. Since software system is composed of black box components (with no source code available), so it is hard to have trust on those components. Thus component selection, evaluation and ranking process is one of the major issues in this area. FANP helps in making efficient decision while selecting the multi criteria component. This methodology helps in quantifying the selection process to enhance the trust on the selected components. This chapter describes the scope of proposed work, the formulation of the multi-criteria component selection problem, the objectives to achieve with the help of proposed methodology and research approaches to be followed to achieve the objectives.

3.1 Scope of the study

Scope of the study is to help the decision maker in the better decision making while selecting and evaluating the software components to build the software system in CBSE.MCDA techniques build confidence to have trust on the selected components i.e. helps in searching the candidate components, shortlist them, selection of relevant ones and their evaluation FUZZY Analytical Network Process (FANP) method better helps in various cases like:

1. Helps in choosing the best alternative when number of alternatives are there to solve the problem and in situations where there is need to fulfil multiple criteria by selecting the appropriate component to enhance the trust on selected component.
2. Helps in ranking the alternatives when there is more than one option available to solve the particular problem to predict the most suitable option and least preferable one.
3. Helps in the allocation of resources among the set of available alternatives to solve the problem.
4. Helps in prioritizing the alternatives in the alternative set.
5. Helps in resolving the conflicts between various alternatives.
6. Helps in reducing the incomparability between two alternatives.

7. Information needed by the decision maker that is information between criteria and information within criteria is easily retrieved.

3.2 Problem Formulation

It is needed to have a method which is simpler and better helps in decision making while obtaining the solution of multi-objective selection of trusted components from the number of available alternatives. FANP solves the problem in an additional way with the additional benefits than the other MCDA methods.

Component selection problem is formulated as a multi criteria problem in which a component or a set of components are selected from the set of alternative components on the basis of satisfying maximum criteria chosen from criteria set .

Let A= $\{a_1, a_2, a_3 \ldots\ldots.. a_n\}$ be the set of 'n' alternatives for the solution of the problem

And C= $\{c_1, c_2, c_3 \ldots\ldots.. c_k\}$ be the set of 'k' criteria as a basis of evaluation and selection.

Problem is defined as: $\max\{c_1(a), c_2(a), c_3(a) \ldots\ldots\ldots c_k(a) | A £ A\}$.

It is needed to select the alternative which fulfills at least one criterion more than others and with greater score values .For the solution of this problem Fuzzy Analytical Network Based methodology is used. Evaluation criteria are selected on the basis of requirements of the users.

3.3 Objectives

1. Study and analysis of Component Based Software Engineering and various challenges in component selection.
2. Defining a classification criterion of components.
3. Performing a quantitative selection and evaluation of components and improving the trustworthiness of the components.
4. Reduce the multiple criteria component selection problem to the form which is easily manipulated.
5. Preparing the repository to maintain the components and evaluation criteria.

6. Graphical representation of the solution for better understanding and for easier solution of the problem.

3.4 Research Methodology

1. In order to achieve the objective "Study and analysis of Component Based Software Engineering and various challenges in component selection and ranking", extensive literature review has been carried out and various challenges in component selection are taken into account such as it is hard to trust the component with no source code available.

2. In order to achieve the objective "Defining a classification criterion of components based on various parameters", the nonfunctional attributes of the components are considered like functionality, reliability, efficiency, usability, maintainability and portability etc .The non-functional requirements or the metrics combine more than two functional criteria and are suitable to be considered as a classification criteria.

3. In order to achieve the objective "Performing the quantitative selection and ranking of component and improving the trustworthiness of components", Fuzzy Analytic Network process (FANP) method is used. In this method it is easy to obtain the partial or complete ranking of number of alternatives and also ranking under constraints. Ranking is based on the evaluation criteria. The best alternative is that which outranks the other alternatives. Then this alternative is used to compose the system .The method uses the following step:

Step 1: Identify goal, criteria, sub criteria, alternatives and clusters to be used in the proposed model.

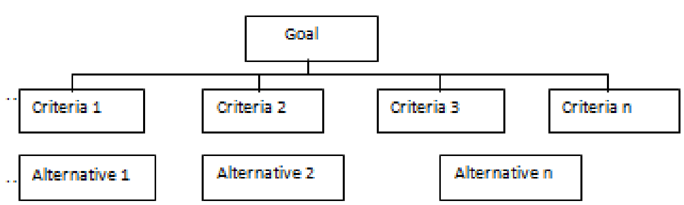

Fig 3.1 Network Structure Of Elements

Step 2: Structure the problem into network including alternatives, criteria's, sub criteria's, clusters and dependencies between them.

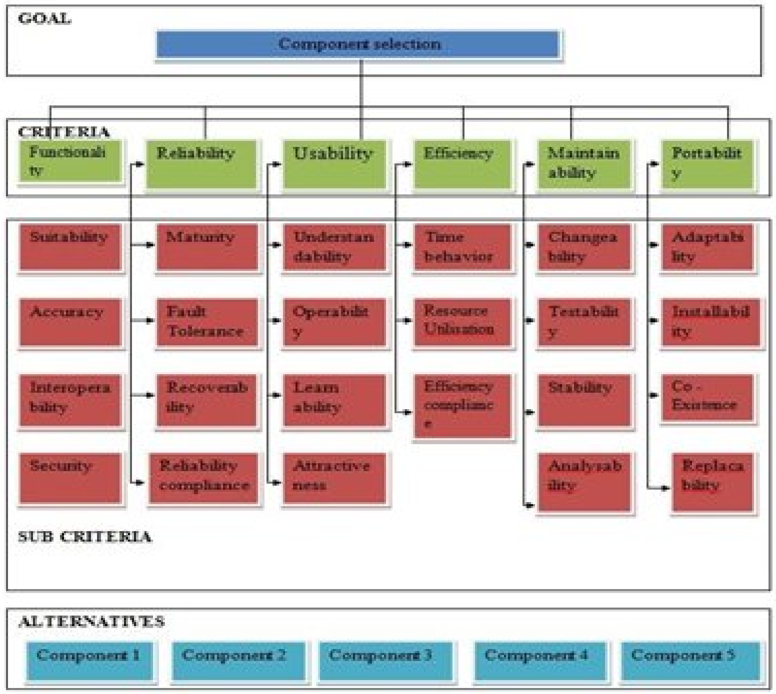

Fig 3.2: Structure of Elements

Step 3: Construct a Pair wise of the components with fuzzy judgments. Pair wise comparison matrices are formed by the experts by applying fuzzy scale given in table below.

Linguistic Term	Fuzzy Number	TFN(l ,m ,u)
Extreme importance	9^{-1}	1/9,1/9,1/9
Very importance	7^{-1}	1/8,1/7,1/6
Essential Unimportance	5^{-1}	1/6,1/5,1/4
Moderate Unimportance	3^{-1}	1/4,1/3,1/2
Equally Importance	1	1,1,1
Moderate Importance	3	2,3,4
Essential Importance	5	4,5,6
Very Vital Importance	7	6,7,8
Extreme Importance	9	9,9,9

Table 3.1: Table of Linguistic Scales

Step 4: Constructing the fuzzy comparison matrix by using triangular fuzzy numbers triangular fuzzy number is defined by three parameters (l, m, u) .l parameter denotes the smallest possible value, m denotes the most promising value and u denotes the largest possible value.

Step 5: Construct an initial super matrix: Super matrix is formed by doing pair wise comparisons between different criteria's The criteria in the "i" row are compared with the criteria in the "j" column in the form of (I, j) .If the criteria of "i" row are superior to "j" column, then it is written as (i, j) and (j, i) is the reciprocal of (i ,j).

		C1	C2	C3	C4	Am
	C1	C2	C3	C4	Am	A1m
C1	1	C12	C13	C14	A1m	A2m
C2	C21	1	C23	C24	A2m	A3m
C3	C31	C32	1	C34	A3m	A4m
C4	C41	C42	C43	1	A4m	

Fig 3.4: Weighted Super Matrix

Step 6: Obtain the weighted super matrix: Weighted super matrix is the one in which all the column sum are equals to one. It is obtained by multiplying the unweighted super matrix by the corresponding cluster priorities.

		Criteria					Alternatives			
		C1	C2	C3	C4	C5	A1	A2	A3	A4
Criteria	C1						V_{A1m}			
	C2						V_{A2m}			
	C3						V_{A3m}			
	C4						V_{A4m}			
	C5						V_{A5m}			
Alternatives	A1	V_{A1m}	V_{A1m}							
	A2	V_{A2m}	V_{A2m}							
	A3	V_{A3m}	V_{A3m}							
	A4	V_{A4m}	V_{A4m}							

Fig 3.5: Weighted Super Matrix

Step 7: Calculate the limit super matrix: Limit the weighted super matrix by raising it to sufficiently large power so that it converges into stable super matrix

$$
\begin{array}{ccc} & & \begin{array}{cccc} C_1 & C_2 & \cdots & C_N \\ e_{11}e_{12}\cdots e_{1n_1} & e_{21}e_{22}\cdots e_{2n_2} & & e_{N1}e_{N2}\cdots e_{Nn_N} \end{array} \\
W = & \begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \end{array} \\ C_2 & \begin{array}{c} e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \end{array} \\ \vdots & \\ C_N & \begin{array}{c} e_{N1} \\ e_{N2} \\ \vdots \\ e_{Nn_N} \end{array} \end{array} & \begin{array}{cccc} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{21} & W_{22} & \cdots & W_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{array} \end{array}
$$

Fig 3.6: Limit Matrix

Step 8: Rank the alternatives by comparing it with the values given in the table 2.

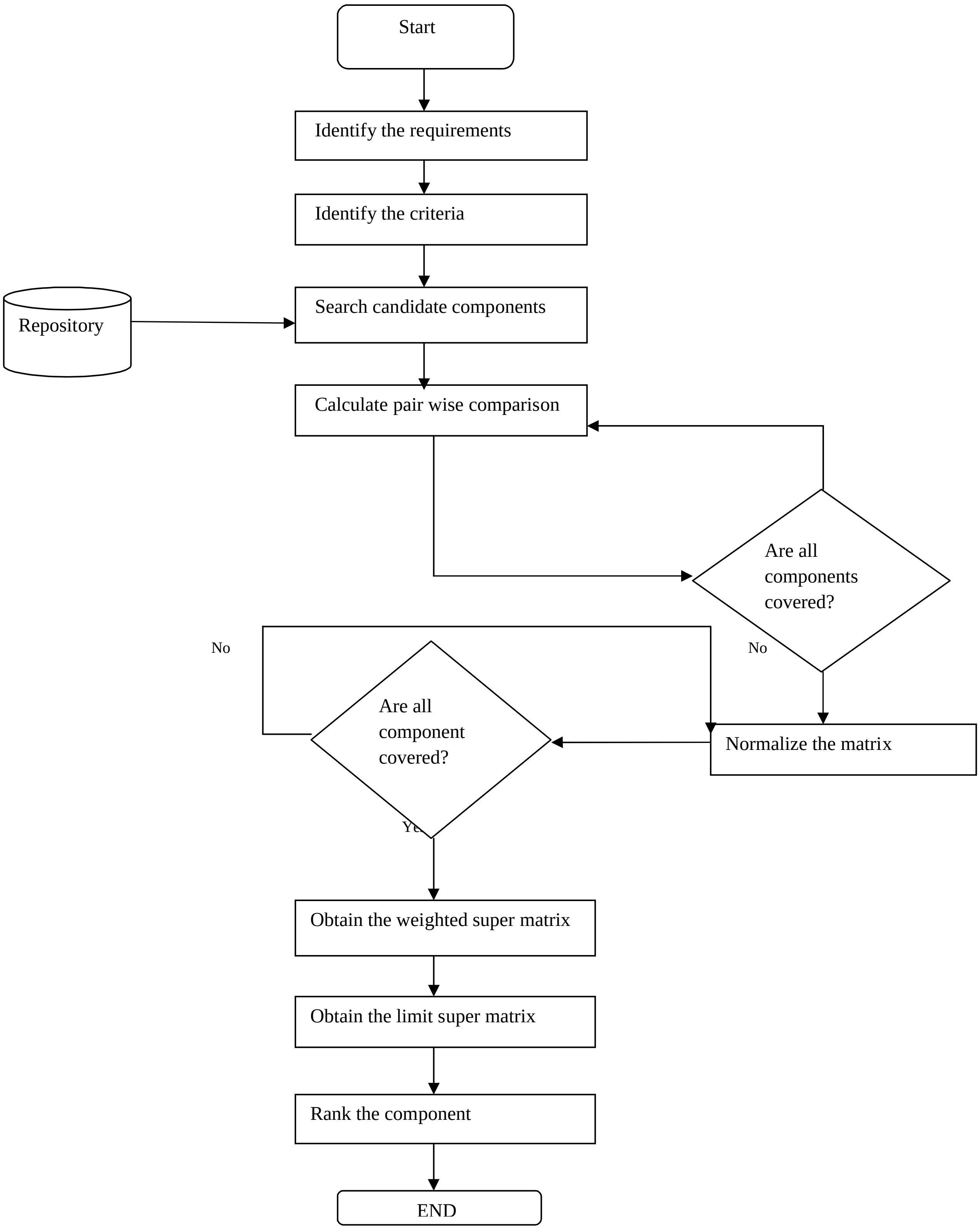

Fig 3.7Flow chart to select and evaluate the components

CHAPTER 4

RESULTS AND CONCLUSIONS

All the objectives are achieved by reviewing the literature and Multi-Criteria Analyzer tool which works on FANP methodology .Repository is maintained with the help of SQL server.

FANP can better support the COTS components selection process while developing the system from those components as compared to other multiple criteria decision analysis techniques. An experiment is performed by evaluating the components using the Multiple –Criteria Analyzer based on FANP methodology justifies the same.

4.1 Experimental Setup and Findings

Components that need to evaluate and the evaluation criteria can be maintained in a repository for current and future references as shown in Fig 4.1. Components set ‘A’ is represented as A = {c1, c2, c3, c4, c5} and Criteria Set ‘S’ is represented as S = {Functionality, Reliability, Efficiency, Usability, Safety, Satisfaction}.

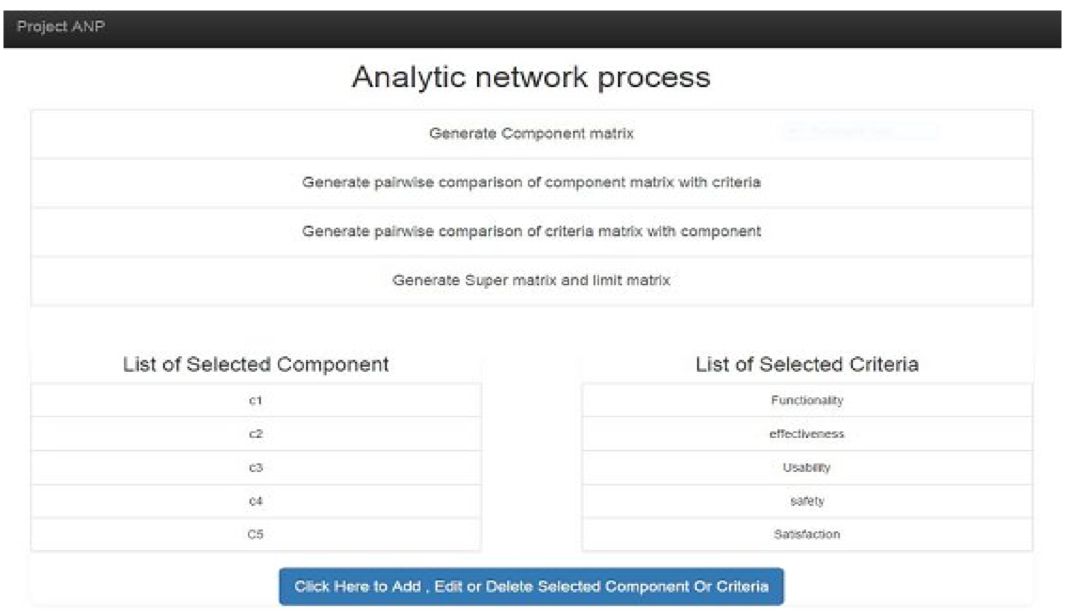

Fig 4.1: Component and Criteria

Fig 4.2: Adding and changing Component and Criteria

Selection of components are done that need to be evaluated .Following Fig 4.3(a) ,4.3(b) shows the status of component i.e. how to add components and change components according to the requirements.

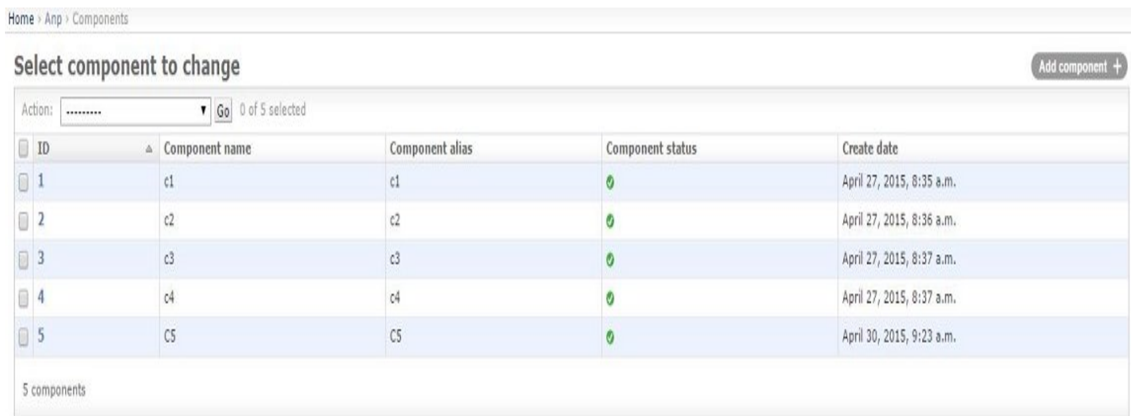

Fig 4.3(a): Adding Component

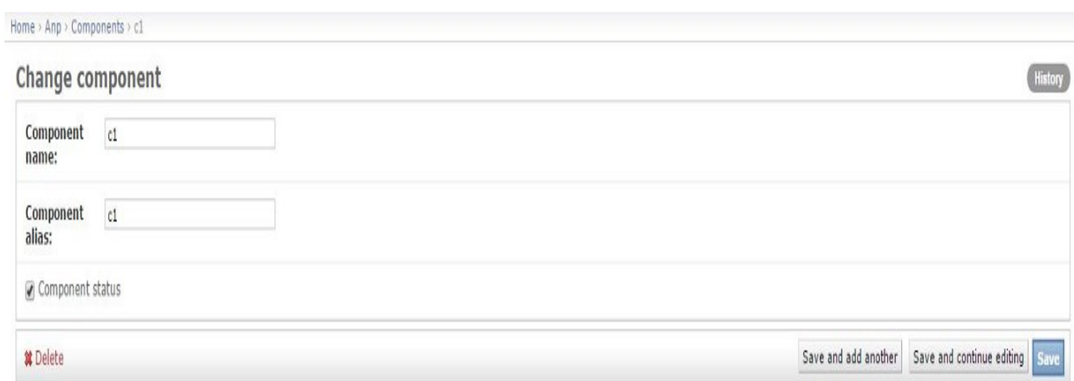

Fig 4.3(b): Changing Component

Selection of criteria is made on the basis of which components will be evaluated and ranked. Following Fig 4.4(a), 4.4(b) shows how to add criteria and change criteria respectively

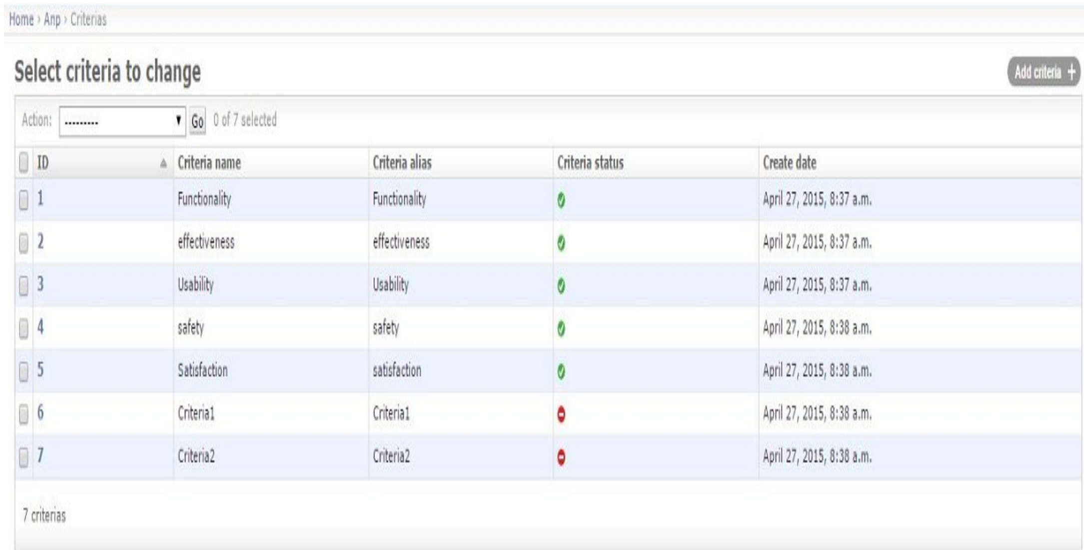

Fig 4.4 (a): Adding Criteria

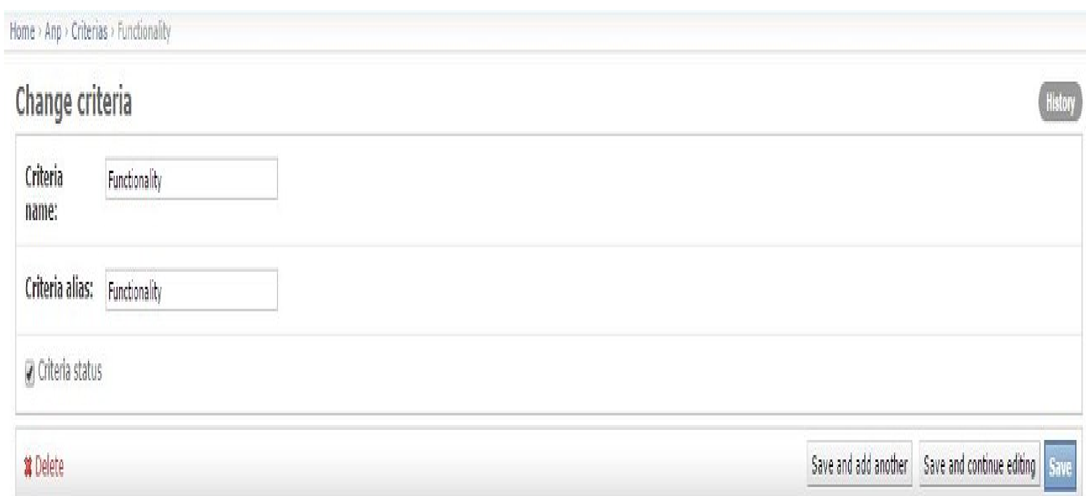

Fig 4.4 (b): Changing Criteria

Pair wise comparison is made between alternatives and component .Following Fig 4.5 shows the pair wise comparison between components by creating a super matrix

Component matrix

	c1	c2	c3	c4	C5
c1	1.000000	9.000000	4.00	3.000000	5
c2	0.111111	1.000000	4.00	3.000000	2
c3	0.250000	0.250000	1.00	4.000000	1
c4	0.333333	0.333333	0.25	1.000000	3
C5	0.200000	0.500000	1.00	0.333333	1

Fig 4.5: Component Super Matrix

Normalized Component matrix

	c1	c2	c3	c4	C5
c1	0.527859	0.812030	0.390244	0.264706	0.416667
c2	0.058651	0.090226	0.390244	0.264706	0.166667
c3	0.131965	0.022556	0.097561	0.352941	0.083333
c4	0.175953	0.030075	0.024390	0.088235	0.250000
C5	0.105572	0.045113	0.097561	0.029412	0.083333

Fig 4.6: Normalized Component Super Matrix

Evector Component matrix

	Evector values
c1	0.482301
c2	0.194099
c3	0.137671
c4	0.113731
C5	0.072198

Fig 4.7: Evector component super matrix

Pair wise comparison is made between selected components for each alternative as shown in the Fig 4.8 (a) ,4.8 (b).4.80 (c),4.8(d),4.8 (e)

Functionality

	c1	c2	c3	c4	C5
c1	1.000000	5.000000	3.0	9.000000	2
c2	0.200000	1.000000	8.0	5.000000	7
c3	0.333333	0.125000	1.0	2.000000	1
c4	0.111111	0.200000	0.5	1.000000	9
C5	0.500000	0.142857	1.0	0.111111	1

Fig 4.8 (a): Pair wise comparison of components with respect to functionality

effectiveness

	c1	c2	c3	c4	C5
c1	1.000000	7.000000	7.000000	3.0	3
c2	0.142857	1.000000	3.000000	9.0	3
c3	0.142857	0.333333	1.000000	3.0	3
c4	0.333333	0.111111	0.333333	1.0	2
C5	0.333333	0.333333	0.333333	0.5	1

Fig 4.8(b): Pair wise Comparison of components with respect to Effectiveness

Usability

	c1	c2	c3	c4	C5
c1	1.000000	9.000000	5.0	1.000000	9
c2	0.111111	1.000000	1.0	8.000000	6
c3	0.200000	1.000000	1.0	5.000000	2
c4	1.000000	0.125000	0.2	1.000000	9
C5	0.111111	0.166667	0.5	0.111111	1

Fig 4.8 (c): Pair wise comparison of components with respect to usability

safety

	c1	c2	c3	c4	C5
c1	1.000000	7.00	5.000	2.00	5
c2	0.142857	1.00	1.000	4.00	2
c3	0.200000	1.00	1.000	8.00	2
c4	0.500000	0.25	0.125	1.00	4
C5	0.200000	0.50	0.500	0.25	1

Fig 4.8 (d): Pair wise comparison of components with respect to safety

Satisfaction

	c1	c2	c3	c4	C5
c1	1.000000	5.000000	9.0	3.000000	9
c2	0.200000	1.000000	2.0	7.000000	5
c3	0.111111	0.500000	1.0	5.000000	5
c4	0.333333	0.142857	0.2	1.000000	6
C5	0.111111	0.200000	0.2	0.166667	1

Fig 4.8 (e): Pair wise comparison of components with respect to satisfaction

Normalized matrix is constructed for all the components with respect to particular criteria as shown in the Fig: 4.9 (a), 4.9(b), 4.9(c), 4.9 (d), 4.9 (e)

Functionality

	c1	c2	c3	c4	C5
c1	0.466321	0.773054	0.222222	0.525974	0.10
c2	0.093264	0.154611	0.592593	0.292208	0.35
c3	0.155440	0.019326	0.074074	0.116883	0.05
c4	0.051813	0.030922	0.037037	0.058442	0.45
C5	0.233161	0.022087	0.074074	0.006494	0.05

Fig 4.9 (a): Normalized matrix of components with respect to functionality

effectiveness

	c1	c2	c3	c4	C5
c1	0.512195	0.797468	0.600000	0.181818	0.250000
c2	0.073171	0.113924	0.257143	0.545455	0.250000
c3	0.073171	0.037975	0.085714	0.181818	0.250000
c4	0.170732	0.012658	0.028571	0.060606	0.166667
C5	0.170732	0.037975	0.028571	0.030303	0.083333

Fig 4.9 (b): Normalized matrix of components with respect to effectiveness

Usability

	c1	c2	c3	c4	C5
c1	0.412844	0.797048	0.649351	0.066176	0.333333
c2	0.045872	0.088561	0.129870	0.529412	0.222222
c3	0.082569	0.088561	0.129870	0.330882	0.074074
c4	0.412844	0.011070	0.025974	0.066176	0.333333
C5	0.045872	0.014760	0.064935	0.007353	0.037037

Fig 4.9 (c): Normalized matrix of components with respect to usability

safety

	c1	c2	c3	c4	C5
c1	0.489510	0.717949	0.655738	0.131148	0.357143
c2	0.069930	0.102564	0.131148	0.262295	0.142857
c3	0.097902	0.102564	0.131148	0.524590	0.142857
c4	0.244755	0.025641	0.016393	0.065574	0.285714
C5	0.097902	0.051282	0.065574	0.016393	0.071429

Fig 4.9 (d): Normalized matrix of components with respect to safety

Satisfaction

	c1	c2	c3	c4	C5
c1	0.569620	0.730689	0.725806	0.185567	0.346154
c2	0.113924	0.146138	0.161290	0.432990	0.192308
c3	0.063291	0.073069	0.080645	0.309278	0.192308
c4	0.189873	0.020877	0.016129	0.061856	0.230769
C5	0.063291	0.029228	0.016129	0.010309	0.038462

Fig 4.9 (e): Normalized matrix of components with respect to satisfaction

Eigen values are calculated for each component with respect to each criteria respectively as shown in the following figure 4.10 (a),4.10(b),4.10 (c), 4.10 (d) ,4.10 (e)

Functionality

	0
c1	0.417514
c2	0.296535
c3	0.083145
c4	0.125643
C5	0.077163

Fig 4.10 (a): Evector matrix of components with respect to functionality

Satisfaction

	0
c1	0.511567
c2	0.209330
c3	0.143718
c4	0.103901
C5	0.031484

Fig 4.10 (b): Evector matrix of components with respect to Satisfaction

Pair wise comparison is done between criteria's for each component (c1, c2, c3, c4, c5) as shown in the following Fig 4.11 (a), 4.11 (b), 4.11(c), 4.11 (d), and 4.11(e)

c1

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	1.000000	1.000	2.000000	9.00	4
effectiveness	1.000000	1.000	2.000000	1.00	8
Usability	0.500000	0.500	1.000000	6.00	1
safety	0.111111	1.000	0.166667	1.00	4
Satisfaction	0.250000	0.125	1.000000	0.25	1

Fig 4.11 (a): Pair wise comparison of criteria's for component c1

c2

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	1.000000	5.000000	6.000000	1.0	2
effectiveness	0.200000	1.000000	1.000000	9.0	5
Usability	0.166667	1.000000	1.000000	6.0	7
safety	1.000000	0.111111	0.166667	1.0	5
Satisfaction	0.500000	0.200000	0.142857	0.2	1

Fig 4.11 (b): Pair wise comparison of criteria's for component c2

c3

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	1.000000	5.000000	3	7.000000	6
effectiveness	0.200000	1.000000	3	7.000000	6
Usability	0.333333	0.333333	1	1.000000	1
safety	0.142857	0.142857	1	1.000000	9
Satisfaction	0.166667	0.166667	1	0.111111	1

Fig 4.11 (c): Pair wise comparison of criteria's for component c3

c4

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	1.000000	8.000000	8.0	7.00	1
effectiveness	0.125000	1.000000	5.0	6.00	4
Usability	0.125000	0.200000	1.0	1.00	5
safety	0.142857	0.166667	1.0	1.00	4
Satisfaction	1.000000	0.250000	0.2	0.25	1

Fig 4.11 (d): Pair wise comparison of criteria's for component c4

C5

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	1.000000	9.000000	7.000000	1.000	5
effectiveness	0.111111	1.000000	5.000000	9.000	2
Usability	0.142857	0.200000	1.000000	6.000	5
safety	1.000000	0.111111	0.166667	1.000	8
Satisfaction	0.200000	0.500000	0.200000	0.125	1

4.11 (e): Pair wise comparison of criteria's for component c5

Normalized matrix is obtained for each criteria's for each selected component as shown in Fig 4.12 (a), 4.12(b), 4.12(c), 4.12(d), 4.12(e)

c1

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	0.349515	0.275862	0.324324	0.521739	0.222222
effectiveness	0.349515	0.275862	0.324324	0.057971	0.444444
Usability	0.174757	0.137931	0.162162	0.347826	0.055556
safety	0.038835	0.275862	0.027027	0.057971	0.222222
Satisfaction	0.087379	0.034483	0.162162	0.014493	0.055556

Fig 4.12 (a): Normalized Matrix for component c1

c2

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	0.348837	0.683891	0.722063	0.058140	0.10
effectiveness	0.069767	0.136778	0.120344	0.523256	0.25
Usability	0.058140	0.136778	0.120344	0.348837	0.35
safety	0.348837	0.015198	0.020057	0.058140	0.25
Satisfaction	0.174419	0.027356	0.017192	0.011628	0.05

Fig 4.12 (b): Normalized Matrix for component c2

c3

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	0.542636	0.752688	0.333333	0.434483	0.260870
effectiveness	0.108527	0.150538	0.333333	0.434483	0.260870
Usability	0.180879	0.050179	0.111111	0.062069	0.043478
safety	0.077519	0.021505	0.111111	0.062069	0.391304
Satisfaction	0.090439	0.025090	0.111111	0.006897	0.043478

Fig 4.12 (c): Normalized Matrix for component c3

c4

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	0.417910	0.831889	0.526316	0.459016	0.066667
effectiveness	0.052239	0.103986	0.328947	0.393443	0.266667
Usability	0.052239	0.020797	0.065789	0.065574	0.333333
safety	0.059701	0.017331	0.065789	0.065574	0.266667
Satisfaction	0.417910	0.025997	0.013158	0.016393	0.066667

Fig 4.12 (d): Normalized matrix for component c4

C5

	Functionality	effectiveness	Usability	safety	Satisfaction
Functionality	0.407503	0.832477	0.523691	0.058394	0.238095
effectiveness	0.045278	0.092497	0.374065	0.525547	0.095238
Usability	0.058215	0.018499	0.074813	0.350365	0.238095
safety	0.407503	0.010277	0.012469	0.058394	0.380952
Satisfaction	0.081501	0.046249	0.014963	0.007299	0.047619

Fig 4.12 (e): Normalized matrix for component c5

Eigen values are calculated for each component as shown in the Fig 4.13(a), 4.13(b),4.13(c),4.13 (d) ,4.13 (e)

c1

	0
Functionality	0.338732
effectiveness	0.290423
Usability	0.175646
safety	0.124383
Satisfaction	0.070814

Fig 4.13: (a) Evector matrix for component c1

c2

	0
Functionality	0.382586
effectiveness	0.220029
Usability	0.202820
safety	0.138446
Satisfaction	0.056119

Fig 4.13: (b) Evector matrix for component c2

c3

	0
Functionality	0.464802
effectiveness	0.257550
Usability	0.089543
safety	0.132702
Satisfaction	0.055403

Fig 4.13 (c): Evector matrix for component c3

c4

	0
Functionality	0.460360
effectiveness	0.229056
Usability	0.107547
safety	0.095012
Satisfaction	0.108025

Fig 4.13 (d): Evector matrix for component c4

C5

	0
Functionality	0.412032
effectiveness	0.226525
Usability	0.147997
safety	0.173919
Satisfaction	0.039526

Fig 4.13 (e): Evector matrix for component c5

When the total sum of a column of a matrix is less than or equal to one, Then this matrix is known as weighted super matrix. The value which is greater than one has to be normalized to one until all the values of columns becomes equal to one.

Weighted super matrix is obtained as shown in the fig 4.14

Super matrix

	Functionality	effectiveness	Usability	safety	Satisfaction	c1	c2	c3	c4	C5
Functionality	0.000000	0.000000	0.000000	0.000000	0.000000	0.338732	0.382586	0.464802	0.460360	0.412032
effectiveness	0.000000	0.000000	0.000000	0.000000	0.000000	0.290423	0.220029	0.257550	0.229056	0.226525
Usability	0.000000	0.000000	0.000000	0.000000	0.000000	0.175646	0.202820	0.089543	0.107547	0.147997
safety	0.000000	0.000000	0.000000	0.000000	0.000000	0.124383	0.138446	0.132702	0.095012	0.173919
Satisfaction	0.000000	0.000000	0.000000	0.000000	0.000000	0.070814	0.056119	0.055403	0.108025	0.039526
c1	0.417514	0.468296	0.451750	0.470297	0.511567	0.000000	0.000000	0.000000	0.000000	0.000000
c2	0.296535	0.247938	0.203187	0.141759	0.209330	0.000000	0.000000	0.000000	0.000000	0.000000
c3	0.083145	0.125736	0.141191	0.199812	0.143718	0.000000	0.000000	0.000000	0.000000	0.000000
c4	0.125643	0.087847	0.169880	0.127616	0.103901	0.000000	0.000000	0.000000	0.000000	0.000000
C5	0.077163	0.070183	0.033991	0.060516	0.031484	0.000000	0.000000	0.000000	0.000000	0.000000

Fig 4.14: Weighted Super matrix

Limit Super matrix

	Functionality	effectiveness	Usability	safety	Satisfaction	c1	c2	c3	c4	C5
Functionality	0.383156	0.381286	0.388596	0.390097	0.380976	0.000000	0.000000	0.000000	0.000000	0.000000
effectiveness	0.254175	0.258961	0.258882	0.262178	0.262575	0.000000	0.000000	0.000000	0.000000	0.000000
Usability	0.165855	0.163635	0.156502	0.151930	0.161014	0.000000	0.000000	0.000000	0.000000	0.000000
safety	0.129377	0.129813	0.125110	0.127289	0.127031	0.000000	0.000000	0.000000	0.000000	0.000000
Satisfaction	0.067436	0.066306	0.070910	0.068507	0.068404	0.000000	0.000000	0.000000	0.000000	0.000000
c1	0.000000	0.000000	0.000000	0.000000	0.000000	0.451502	0.448217	0.445874	0.448003	0.446982
c2	0.000000	0.000000	0.000000	0.000000	0.000000	0.240598	0.240588	0.250290	0.251238	0.241346
c3	0.000000	0.000000	0.000000	0.000000	0.000000	0.124511	0.123840	0.118150	0.116771	0.124068
c4	0.000000	0.000000	0.000000	0.000000	0.000000	0.121142	0.125352	0.118927	0.119582	0.123112
C5	0.000000	0.000000	0.000000	0.000000	0.000000	0.062248	0.062003	0.066760	0.064405	0.064492

Fig 4.15: Limit matrix

Action Profiles can be obtained from Dimensionless matrix which indicates the graphical representation of the performance of an alternative component on all criteria. Action profiles of all the components are shown in the Fig 4.16(a), 4.16(b), 4.16(c), 4.16(d), 4.16(e)

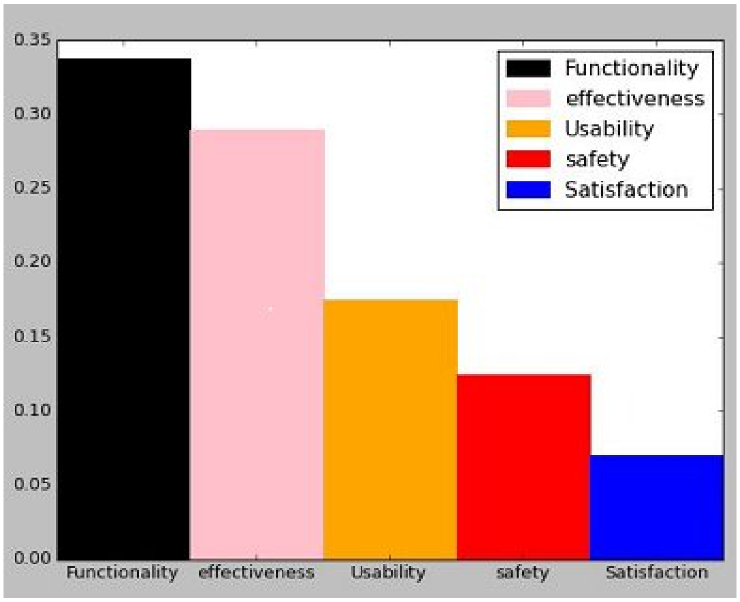

Fig 4.16(a): Graphical representation of component c1

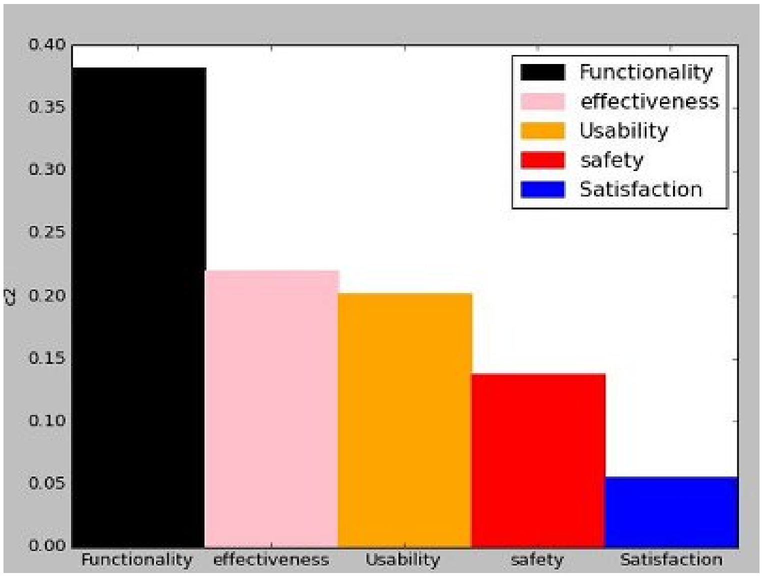

Fig 4.16(b): Graphical representation of component c2

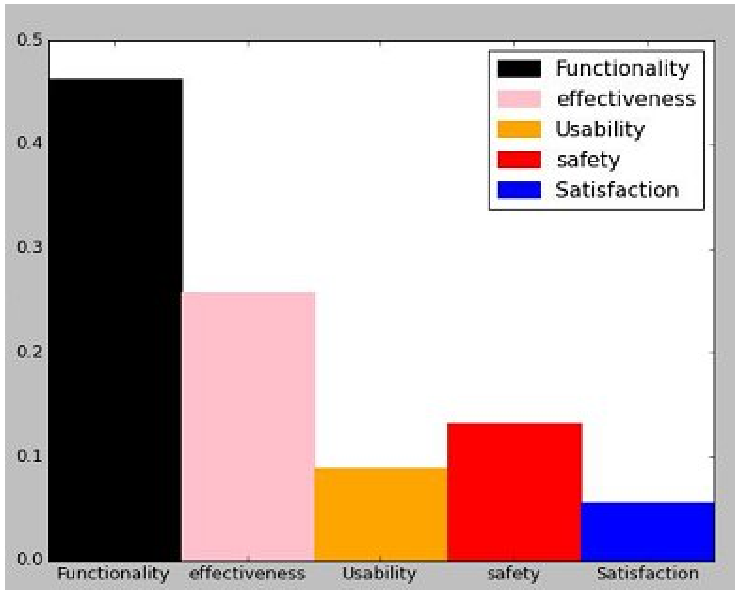

Fig 4.16 (c): Graphical representation of component c3

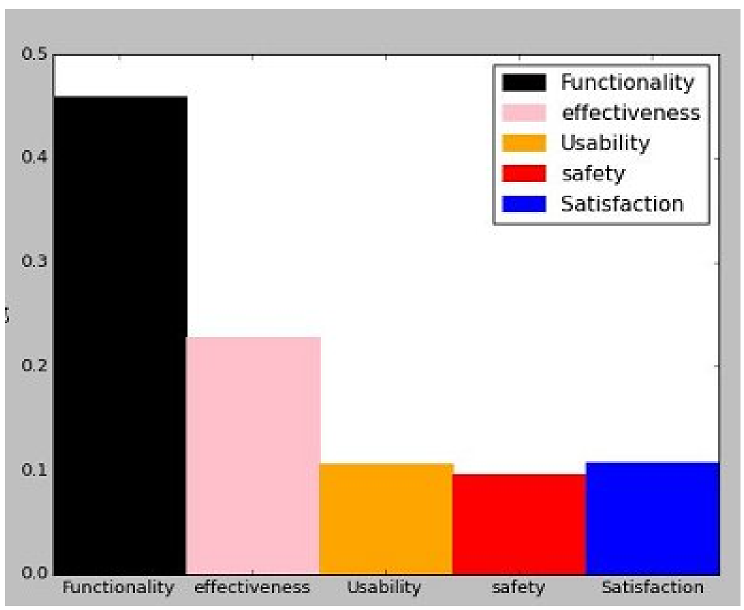

Fig 4.16(d): Graphical representation of component c4

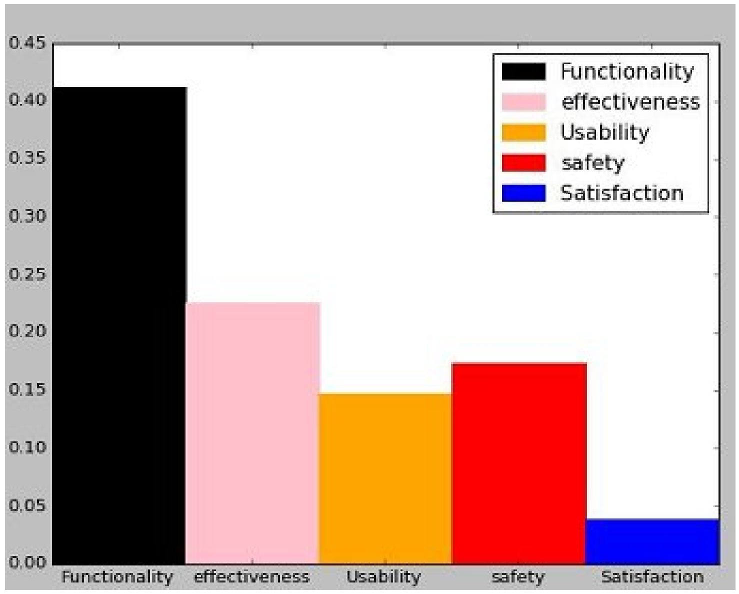

Fig 4.16(e): Graphical representation of component c5

Ranking of all components obtained by comparing its value from the linguistic scales of table as discussed above as shown in the Fig 4.17 (a) and 4.17 (b).

Result and Conclusion

c1	0.461447542996	Moderate UnImportance
c2	0.197405541539	Esstential UnImportance
c3	0.152110159596	Very Importance
c4	0.145775765992	Very Importance
C5	0.0432609898774	Extreme Importance

Fig 4.17 (a): Ranking of selected components

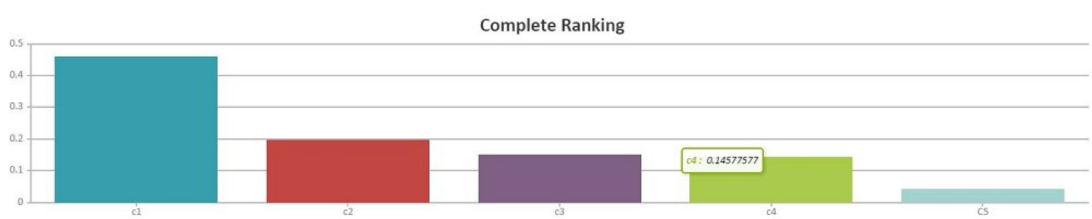

Fig 4.17 (b): Graphical representation of ranking of selected components

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 Conclusion

- Using the FANP based approach methodology; it simplifies the complex problem of selection and ranking the component based on quantitative and qualitative phenomenon
- Choosing the criteria and adding the components is straightforward and there is no limit on the number of criteria or the components to compare.
- Choosing the criteria and assigning the weights to component is simple
- It can help to manage and control change in COTS based development systems.
- There is no constraint on the criteria weight that it must be summed as 1.
- Decision maker can set his own weight or he has opportunity to fix the same weight to all criteria.

5.2 Future Scope

- Component selection process will be extended by placing the constraints on the criteria and components.
- Requirements from multiple participants having conflicting requirements can also be evaluated.
- The winning requirements can be used for the evaluation of alternative components.
- The proposed work can also be extended by developing the trust model for the selected components to quantify the trustworthiness of the components.
- Sub criteria can be also taken into account for component selection and ranking.

CHAPTER 6
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APPENDIX

Abbreviations

- **AHP-** Analytic Hierarchy Process
- **ANP-** Analytic Network Process
- **BBN-** Bayesian Belief Network
- **CBSE-**Component Based Software Engineering
- **CBD-** Component Based Development
- **COTS-**Commercial Off The Shelf
- **DesCOTS-**Description, Evaluation and Selection of COTS components
- **HKBS-**Hybrid Knowledge Based System
- **MCDA-** Multi Criteria Decision Analysis
- **PLD-**Product Line Development
- **PROMETHEE-**Preference Ranking Organization Method for Enrichment Evaluation
- **SMART-**Simple Multi-Attribute Rating Technique
- **WSM-** Weighted Scoring Method

Glossary

- **Methodology –** Collection of Principles and practice
- **Process –** The procedure for working
- **Evaluation-** Act of rating the alternatives