Pertanika J. Sci. & Technol. 25 (3): 871 - 890 (2017)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Dealing with Interdependency among NFR using ISM

Kaur, H.* and Sharma, A.

Institute of Engineering and Technology, Department of Computer Engineering & Applications, GLA University, Mathura, Uttar Pradesh 281406, India

ABSTRACT

Non-Functional Requirements (NFRs) determine the utility and effectiveness of a framework. Due to the subjective nature and complexity of NFRs, it is quite unrealistic to concentrate on each NFR. Consequently, agreement between groups of cross-utilitarian and cross functional decision makers are important. This paper models NFRs in the form of Soft Goal Interdependency Digraph (SID). The SID is based on Interpretive Structural Modelling (ISM) method which in turn utilises MICMAC (Matrices Impacts Croise's Multiplication Appliquée a UN Classement) and AHP (Analytic Hierarchy Process) approaches for identification of critical NFRs. These objectives allow the analysts and developers to accept the best possible trade off choices among NFRs. This is discussed using a general case of cafeteria ordering framework. The proposed model contrasts well with other positioning methodologies.

Keywords: Analytic Hierarchy Process, Interpretive Structural Modelling, Matrices Impacts Croise's Multiplication Appliquée a UN Classement, Non-Functional requirements, sensitivity analysis

INTRODUCTION

Non-functional requirements (NFRs) assume a pivotal role in determining the most critical requirements when presented with an array of choices. The expression "Non-functional requirements " are utilised to allude to the greater part of the data framework other than the sought and desired functional prerequisites. However, surprisingly, NFRs have are often incorporated very late into the process of framework design (Chung et al., 2009). To add to system woes, NFRs are hidden inside computer software program specifications as remarks. Over the years, numerous strategies and procedures have been proposed to enhance their elicitation, documentation, and approval. Yet, at the same time, it is impractical to allocate same amount time on each NFR during program development and improvement stages as they are complex. Thus, there is a need to settle for best possible choice among the NFRs.

Article history:
Received: 29 December 2016
Accepted: 21 April 2017

E-mail addresses:
harsimran.31@gmail.com (Kaur, H.),
ashish.sharma@gla.ac.in (Sharma, A.)
*Corresponding Author

ISSN: 0128-7680 © 2017 Universiti Putra Malaysia Press.

The NFRs are unpredictable (Chung et al., 2009) and thus this paper considers the issues related to identifying critical NFRs and determining degree of mutual reliance between them to help software analysts in managing such NFRs for their programs.

This paper also examines the integration between ISM and AHP, in order to show interdependencies between NFRs. It does this by generating Softgoal Interdependency Digraph (SID) and MICMAC analysis to showcase critical NFRs.

The validity and favourable circumstances of the proposed methodology are discussed using model. In order to examine the credibility of this proposed model, it was initially analysed individually before it is compared with others built up and noticeable methodologies proposed in the past.

There are many definitions of NFR in the literature. Chung et al. (2009) questions that "in the presence of so many different definitions on NFR how should we proceed". In their paper, they define it as: f: I → O (e.g., sum: int x int → int), just about anything that addresses characteristics of f, I, O or relationships between I and O will be considered NFRs. As per IEEE (2010) "non-functional requirement (NFR) – in software system engineering, a software requirement that describes not what the software will do, but how the software will do it, for example, software performance requirements, software external interface requirements, design constraints, and software quality attributes".

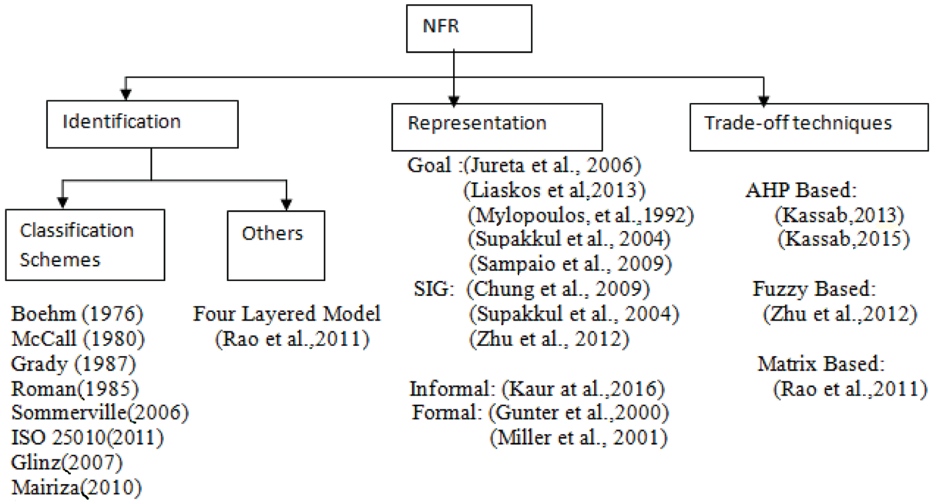

Figure 1. Different NFR schemes from literature

Boehm (1976), McCall (1980), Roman (1985), Grady (1987), Sommerville (2006), Glinz (2007), Mairiza (2010), Chung (2009) addressed ways to identify and classify NFRs. Boehm proposed both quality and quantitative approach to software quality while McCall attempted to bridge the gap between users and developers by focusing on a number of software quality factor that reflect both the users' views and the developers' priorities. Roman focused on consumer-oriented attributes such as performance, design and adaptation as well as on technically-oriented attributes such as functional scope Grady proposed FURPS which has two categories of requirement: Functional (F) and Non-Functional (URPS). At present, the ISO 25010 (2011) model is considered as the standard model for identification of NFRs. Glinz proposed a rethink of the notion of NFRs as there is no fact which explains the meaning of NFR. Some prominent schemes for identification, representation and trade-off for NFR are shown in Figure 1. Not one of the models was able to solve unpredictability associated with managing assorted qualities in number of NFRs and their entomb reliance on each other that an analyst faces during initial phase of software development.

The NFR are represented separately from functional requirements, usually in the form of simple sentences. It is contained under section 3 of IEEE recommended practice for software requirement specifications. Many other initial approaches such as NFR Framework (Juteta et al., 2006) and UML which deals with NFRs informally have been discussed in literature. To address the changing needs of many different classes of users related to NFR a novel approach is discussed by Kaur et al. (2016). It is difficult to determine the degree of mutual reliance between them when there are large number of NFRs with the above representation techniques.

There have been only a few studies on NFR ranking in software systems to date but those are very specific to the particular software application. Some of the ranking techniques for NFR are discussed here. Karlsson, Wohlin, and Regnell (1998) concluded AHP technique to be the most promising method to prioritize requirements. Liaskos, Jalman, and Aranda (2013) used AHP in their model by mapping every OR-decomposition in the goal model into a separate decision problem. They treated all NFRs as mandatory which is not possible in praxis. Elahi and Yu (2011) describe the Requirements Hierarchy Approach (RHA), a quantifiable method to measure and manipulate the effects that NFRs have on a system without focusing on NFR interdependencies. Firesmith (2004) discussed various prioritisation techniques in his paper but did not prioritise it mathematically. Kassab (2013, 2015) provides a set of specialised guidelines to transform the hierarchy that visualise the NFR framework into an AHP decision hierarchy. It focused on pragmatic solution to rank the alternative operationalisations that satisfy NFRs while considering their interdependencies. But there is need to check for inconsistency of the priorities calculated by AHP. Zhu et al. (2012) proposes a fuzzy qualitative and quantitative soft goal interdependency graphs (FQQSIG) model for non-functional requirement correlations analysis in Trustworthy Software and presents a tool based on Matlab. It used the Relation Matrix algorithm that to cope with the negative impact along with the positive impact among NFRs. In this proposed model, ISM is integrated with AHP to generate soft goal diagraph for identified NFR.

This paper proposes a model which generates soft goal interdependency digraph. The model integrates qualitative and quantitative methods to describe, analyse, calculate, and evaluate the critical NFRs for a particular system. Finally, it gives the choice result for decision-makers to select critical NFRs as discussed in next section.

METHODS

The proposed methodology is one that coordinates ISM (Digalwar, 2013) and AHP (Saaty, 2008) procedures to manage mutual correlation among critical NFR; it does this by producing Soft-Goal Inter-Dependency Digraph. The proposed model involves a five-stage method as shown in Figure 2.

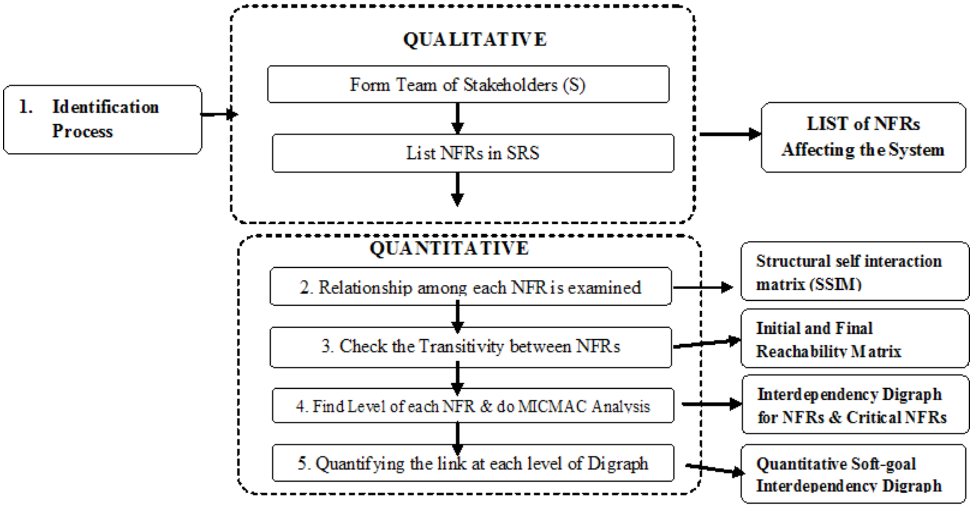

Figure 2. Model process (Five-Step Analysis)

Identification Process

It is important to discuss the NFR choice procedure. There is a group of cross-functional partners that assume diverse roles in programming advancement process for managing NFRs. In this paper, the partner (specialists) constitutes two academicians in the area of program building and program design respectively from a software company. Critical NFRs recognised using Software Requirement Specification (SRS) are then investigated by group of specialists to determine the relationship among NFRs.

Relationship among each NFR

For a strategic analysis of NFRs, it is important to identify and recognise the relationship between each NFR. This leads to accomplishment of Self-Connection Grid (SSIM). The specialists (as discussed in section 3.1) are then consulted to indicate the relevant correlations among the NFRs. Relationship between these *N* elements can be then represented in a matrix known as Structural Self-Interaction Matrix (SSIM), which is developed on the basis of pair-wise comparison of variables which is in turn based on a set of rules specified below:

$$A = (a_{ij})_{N*N}.\, a_{ij} = 1$$

$$NFR = \{n_i \mid (i=1, 2, \ldots, n)\}$$

V – NFR i will depend on NFR j.

A – NFR j depends on NFR i.

X – NFR i and j depend on each other.

O – NFR i and j are unrelated NFR's (1)

Reachability matrix can be then framed from the SSIM and which is later analysed for transitivity.

Check Transitivity between NFRs

The fundamental assumption made in ISM is about transitivity of contextual relationships of NFRs and the transitivity closure of A is defined as

$$\hat{A}=A\oplus A^{2}\oplus A^{3}\oplus \ldots\ldots\ldots\ldots A^{P} \tag{2}$$

while reachability matrix is defined as

$$R=\hat{A}\oplus I=(A+I)^{P..} \tag{3}$$

To evaluate the transitivity between NFRs, SSIM was transformed into a binary matrix, also better known as Initial Reachability Matrix by simply replacing V, A, X and O by 1 and 0 as per the rules (Digalwar, 2013).

MICMAC ANALYSIS

Once the final Reachability Matrix has been designed, then segmentations are done keeping in mind the goal of discovering the chain of command for each of the NFR. The Reachability and predecessor set for each NFR was determined; it essentially incorporates NFR and other NFRs on which it might rely upon. The antecedent set comprises NFR itself and alternate NFRs which rely on it. At this point, the convergence of these sets is inferred for all NFRs. The NFR for which the reachability and intersection point sets are same, assume top-level NFR position in the ISM hierarchy. Once the top-level NFRs are recognised, they are then isolated from all other NFRs and, the same procedure is then repeated for the next level. With Â and R, Soft Goal Interdependency Diagraph of components is plotted and MICMAC is inferred by summing up the samples of all possible conceivable outcomes of interactions in the row. The reliance of the NFR is determined by computing the sum of sections of potential outcomes of collaborations in the columns. The NFRs are arranged into four groups as shown in Table 1, also better known as Cross Impact Matrix Multiplication (MICMAC Analysis).

Table 1
Different classification of NFRs made during MICMAC Analysis [3]

Groups	Description
Autonomous NFR (Not Critical)	The NFRs are relatively disconnected from the system framework and thus, they can be ignored
Dependant NFRs (Critical NFR)	These NFRs are totally dependent on other NFRs
Linkage NFRs (Most Critical NFRs)	Any activity on these NFRs will affect alternate NFRs; furthermore, feedback may have an impact on them, which may intensify with any moves or measures
Independent NFRs (Less Critical)	These NFRs can also be put on hold in case of limited resources.

The driving force of the NFR can be inferred by summing the sections of potential outcomes of collaborations in rows, while the reliance power of the NFR is dictated by summing samples of conceivable outcomes of connections in the column of Reachability Matrix.

Quantifying the Link at each Level of Diagraph

AHPs are utilised to evaluate the priority of NFRs at every level using a digraph (Saaty, 2008). It is an effective tool for managing complex decision making, and may help the decision maker to set needs and settle for the best possible choice. Pair-wise correlation between NFRs is performed at every level chosen by ISM. A pair wise comparison matrix **A** is then created using AHP, where **A** represents a real matrix of dimension $m \times m$, where m represents total evaluation criterions weighed. Every element m_{jk} of matrix A, speaks about the significance of jth criterion in respect to kth one subjected to condition that if ajk < 1, then the jth basis is less critical than the kth paradigm. On the off chance that two criteria have the same significance, then the passage ajk is 1 i.e. ajk.akj=1

$$A=[a_{jk}]_{n\times n}= \begin{bmatrix} 1 & a_{12}\dots & a_{1n} \\ \frac{1}{a_{12}} & 1\dots & a_{2n} \\ & & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}}\dots & 1 \end{bmatrix} \quad (4)\ [26]$$

Subject to $a_{kj}=1/a_{jk}$

$$\begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2}\dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2}\dots & \frac{w_2}{w_n} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \frac{w_n}{w_1} & \frac{w_n}{w_2}\dots & \frac{w_n}{w_n} \end{bmatrix} * \begin{bmatrix} w_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ w_n \end{bmatrix} = n \begin{bmatrix} nw_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ nw_n \end{bmatrix} \quad (5)[26]$$

$A \times W = n.W$

Consistency ratio has not been calculated as the consistency and transitivity has already been sorted by ISM. The Complete approach is discussed in the later section using relevant examples.

RESULTS

Lucid variant of Cafeteria Ordering System (COS) (Weigers et al., 2013) that allows Process Impact workers to request supper from the company cafeteria which are ordered on-line and to be delivered to specific requested destinations has been discussed in the earlier section. Here, NFRs have been taken (effectively recognised) from Software Requirement Specification (SRS), hence Identification Process of this Model was deliberately skipped. A rundown of NFRs distinguished in SRS for COS is seen in Table 2. The complete procedure for Cafeteria Ordering System is discussed below.

1. Two academicians were consulted simultaneously to draw a line of distinction between NFRs. In creating SSIM (Table 4), four symbols (V, A, X, 0) were used to represent the degree of coherence between two NFRs, i and j.

Table 2
NFRs in COS

NFR		NFR requirements	Referred As
Performance	PE-1:	The system shall oblige 400 clients during the peak time usage window from 8 am to 10am, with normal average session span of 8 minutes.	N1
	PE-2:	All Web pages created by the system framework should be completely downloadable in close to 10 seconds over a 40KBps modem association.	N2
	PE-3:	Reactions to questions should not take more than 7 seconds to stack onto the screen after the client presents the inquiry	N3
	PE-4:	The framework should show affirmation messages to clients 4 seconds after the latter submit an initial information to the framework	N4
Security	SE-1:	network transactions which may be either financial of personal identifiable, must be encrypted per BR-33 standard.	N5
	SE-2:	Clients will be required to sign in to the specially designed Cafeteria Ordering System for all operations except menu options.	N6
	SE-3:	Benefactors should log in into the restricted computer system access policy as per the BR-35 standard.	N7
	SE-4:	The system must privilege cafeteria staff individuals only who are listed approved Menu Managers to make or alter menus, per BR-24 standard.	N8
	SE-5:	Only the users who have been authorised for home access to the corporate Intranet may utilise the COS from non-organisation areas.	N9
	SE-6:	The system should allow Patrons to view only their placed orders while the order history of any other patron should be restricted from any unauthorised persons.	N10
Robustness		On the off chance that the association between the client and the system terminates before a request is being either confirmed or scratched off, the Cafeteria Ordering System must empower the user to recoup an incomplete request.	N11
Availability		The Cafeteria Ordering System should be accessible to clients on the corporate Intranet and to dial-in clients with an up-time of 99.9% for local time between 5 am and 12 am and with compromised time of about 95% for duration between 12 midnight and 5am.	N12

Table 3
Structural Self-Interaction Matrix (SSIM)

	N12	N11	N10	N9	N8	N7	N6	N5	N4	N3	N2	N1
N1	X	V	0	X	0	V	V	V	V	V	V	X
N2	V	V	0	X	0	V	V	V	V	V	X	
N3	V	X	0	V	0	V	V	V	0	X		
N4	V	X	0	V	0	V	V	V	X			
N5	V	X	0	0	0	X	0	X				
N6	V	0	0	A	0	X	X					
N7	V	A	X	X	X	X						
N8	0	0	0	0	X							
N9	V	A	A	X								
N10	V	0	X									
N11	V	X										
N12	X											

Table 4
Initial Reachability Matrix

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
N1	1	1	1	1	1	1	1	0	1	0	1	1
N2	0	1	1	1	1	1	1	0	1	0	1	1
N3	0	0	1	1	1	1	1	0	1	0	1	1
N4	0	0	1	1	1	1	1	0	1	0	1	1
N5	0	0	0	0	1	0	0	0	0	0	1	1
N6	0	0	0	0	0	1	1	0	0	0	0	1
N7	0	0	0	0	0	0	1	1	0	0	0	0
N8	0	0	0	0	0	0	1	1	0	0	0	0
N9	1	1	0	0	0	1	1	0	1	0	0	1
N10	0	0	0	0	0	0	1	0	1	0	0	1
N11	0	0	1	1	1	0	1	0	1	0	1	1
N12	1	0	0	0	0	0	0	0	0	0	0	1

Table 5
Final Reachability Matrix

	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	Driver Power
N1	1	1	1	1	1	1	1	0	1	0	1	1	10
N2	0	1	1	1	1	1	1	0	1	0	1	1	9
N3	0	0	1	1	1	1	1	0	1	0	1	1	8
N4	0	0	1	1	1	1	1	0	1	0	1	1	8
N5	0	0	0	0	1	0	(1)	0	0	0	1	1	4
N6	0	0	0	0	0	1	1	0	(1)	0	0	1	4
N7	0	0	0	0	0	0	1	1	0	0	0	0	5
N8	0	0	0	0	0	0	1	1	0	0	0	0	2
N9	1	1	0	0	0	1	1	0	1	0	0	1	6
N10	0	0	0	0	0	0	1	0	1	0	0	1	5
N11	0	0	1	1	1	0	1	0	1	0	1	1	8
N12	1	0	0	0	0	0	0	0	0	0	0	1	2
Dependence Power	3	3	5	5	6	9	11	1	9	2	6	11	

1. The SSIM has been changed over into a binary grid, named Initial Reachability Matrix as shown in Table 4, by substituting V, A, X, O with either 1 or 0. By applying the tenets discussed in section 3, an underlying reachability framework for the NFRs to execute COS is acquired. The last reachability matrix is then acquired by including transitivity as discussed before (Table 5 shows the final outcomes of above mentioned operations).
2. The driving force and the reliance power of every hindrance have likewise been complied in the Table 6 while Soft goal interdependency digraph generated on the basis of Table 7 is shown in Figure 5.

Table 6
Level of Objective Criteria

NFRs	Reachability set	Antecedent Set	Intersection Set	Level
N1	1,2,3,4,5,6,7,9,11,12	1,9,12	1,9,12	1
N2	2,3,4,5,6,7,9,11,12	1,2 ,9,12	2,9	2
N3	3,4,5,6,7,9,11,12	1,2,3,4,11	3,4,11	4
N4	3,4,5,6,7,9,11,12	1,2,3,4,11	3,4,11	4
N5	5,7,11,12	1,2,3,4,5,11	5,11	5
N6	6,7,9,12	1,2,3,4,6,7,9	6,7,9	5
N7	6,7,9,12	1,2,3,4,5,6,7,8,9,10,11	6,7,9	6
N8	7,8	8	8	1
N9	1,2,6,7,9,12	1,2,3,4,6,7,9,10	1,2,6,7,9	4
N10	7,9,10,12	7,10	7	3
N11	3,4,5,7,9,11,12	1,2,3,4,5,11	3,4,5,11	3
N12	1,12	1,2,3,4,5,6,7,9,10,11,12	1,12	7

The links between the NFRs are drawn as per the relationships shown in the reachability matrix. A simpler version of the initial diagraph is obtained by eliminating the transitive relationships step-by-step by examining their interpretation from the knowledge base as shown in Figure 3.

Further NFRs are classified as autonomous, dependent, linkage and independent NFRs which are in turn based on estimations of dependence and driver power as shown in Figure 4. The present study showed robustness, Availability and Security were the critical NFRs which cannot be overlooked regardless of situation; they can easily compromise with Performance parameter which is a less critical NFR. The disentangled digraph after filtering out Autonomous NFRs is shown in Figure 5 while Figure 6 represents the remaining ones after removal of independent NFRs.

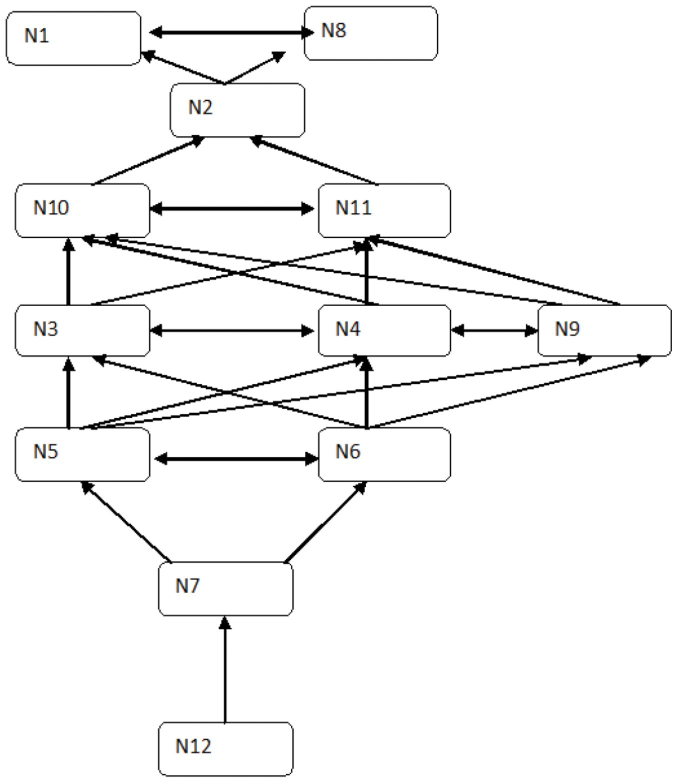

Figure 3. Softgoal interdependency digraph for NFRs

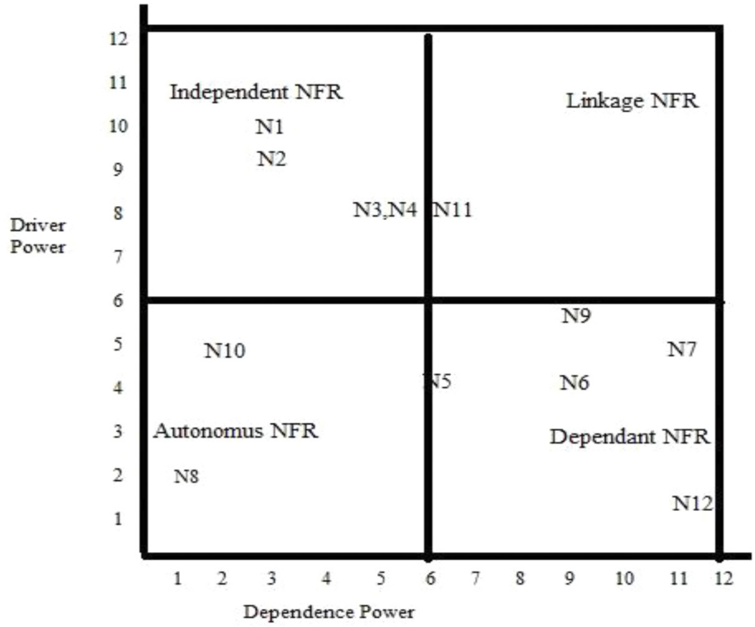

Figure 4. NFR classification

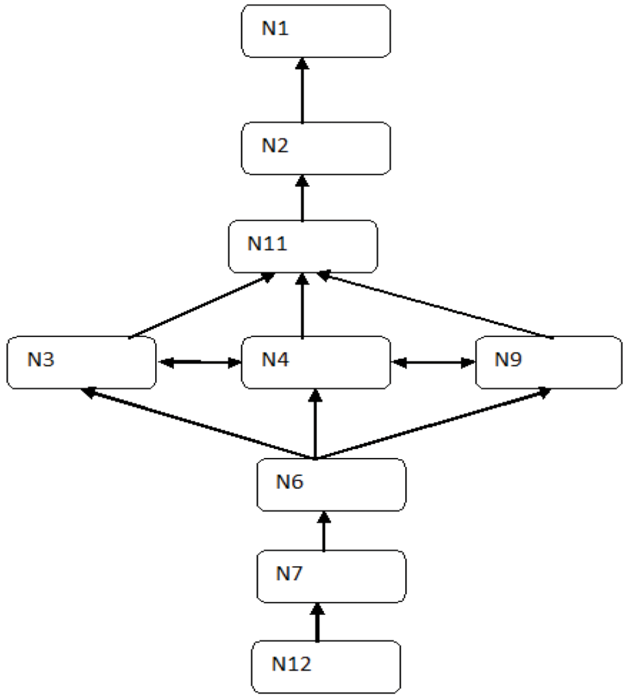

Figure 5. Simplified softgoal interdependency digraph on removing autonomous NFR

Final Simplified graph shows that there is only one NFR at each level as seen in Fig 8, but in cases where there are more than one NFR at each level then AHP may be applied to prioritise NFR at each level of hierarchy.

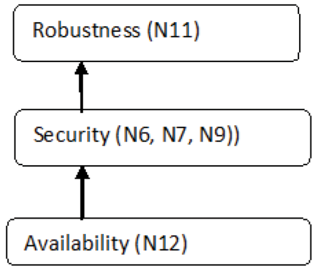

Figure 6. Normalized softgoal interdependency digraph on removing independent

Critical Findings of Application of Proposed Approach on COS

1. Approach helps the members in creating and elucidating the Non-Functional Requirements that are to be organized.
2. Ranks of the criterions, in view of their driving powers showcase that the strength and accessibility are the key functionalities of this model while security and performance are other complimentary criterions.

3. Autonomous NFRs: These NFRs are relatively disengaged from the system framework and can be overlooked. N5, N8 and N10 are self-sufficient NFRs in this illustration.
4. Dependent NFRs: These NFRs are having solid reliance and frail driver, thus they can't be overlooked. N6, N7, N9 and N12 were observed to be the Dependant NFR.
5. Linkage NFRs: These NFRs are having solid driving and reliance power, so they should be considered in every phase of programming development and improvement. In this example N11 characterizes as Linkage NFR.
6. Independent NFRs: These NFRs condition the various NFRs, while being unaffected by them consequently. These NFRs can likewise be put on hold in the event of constrained resources. N1, N2, N3, N4 were observed to be the autonomous NFRs for this particular case study.
7. Also from the map, it was observed that Robustness (N11) was in-fact the top-notch basis while Security traits can be considered as secondary level parameter followed by accessibility and then later with miscellaneous criterions occupying lowers levels on priority hierarchy.

DISCUSSION

In contrasting the present assessment model with the ones proposed by Karlsson, Wohlin, and Regnell (1998), this study found AHP system to be the most encouraging strategy to exchange off necessities. In the current study, NFRs alongside their interdependencies were handled by applying coordinated methodology of ISM and AHP. Liaskos (2013) connected AHP to the goal model by mapping each OR-decomposition in the objective model into a distinct decision making problem. They regard all non-useful necessities as obligatory which is not essentially conceivable; thus, the present study used MICMAC to discover basic NFRs so they are not disregarded even if there occurs a case of restricted assets. Zhu et al. (2012) proposes a fuzzy quantitative and quantitative soft goal interdependency charts (FQQSIG) model with an objective of determining NFRs' correlations using Trustworthy Software and present them using Matlab based tool. The Relation Matrix calculation has been extensively used to determine its negative and the positive effects on NFRs. This was further simplified by adopting MICMAC investigation and analysis methodology by highlighting the reliance and driving force between NFRs.

In this paper, PriEst (Siraj, 2013), was used as an intuitive choice bolster tool to estimate needs from pairwise correlation judgments to contrast with existing exchange off methodologies available in literature. This tool permits clients to choose distinctive prioritisation strategies to gauge inclinations from the same arrangement of judgments. Likewise, it also offers additional techniques to enhance the decision maker's understanding and permit strategy assessment simultaneously. Table 6 shows an analysis of positioning Techniques AHP, Fuzzy, Traceability Matrix(TM) and Proposed Approach based on six parameters.

In the first place the parameters are positioned with the assistance of PriEsT tool. The weights for parameters ascertained by utilising eigenvector technique (EV) and geometric mean (GM) are listed in Table 7. Managing Interdependencies (wP3) and Modelling Structure to manage interdependencies (wP6) were found to be the most essential measure for looking at four different alternative methods for Trade-off for NFR as shown in Figure 7.

Table 6
Analysis of various ranking methods for NFRs based on multiple parameters

	AHP	**Fuzzy**	**Traceability Matrix**	**Proposed Approach**
Concept	Expressive	Expressive, logic based, formal	Simple Goal and Rule Based	visible, well-defined models
Individual Concerns of Stakeholders	Negligible	Negligible	Less	Negligible
Subjectivity	Very high	Very high	Less	Moderate
Dealing Interdependencies	Yes	Limited	No	Yes
Find Criticality of NFRs	Negligible	Negligible	Find critical NFRs	Find further categorisation of critical NFRs
Quantitative	Yes	Yes	No	Yes
Modelling Structure to deal with Interdependencies	Hierarchical tree	Does not deal	Does not deal	Interdependency Diagraph

The proposed Technique is considered the most preferred on the basis of parameters (P1-P6) with weight of 46.7% followed by fuzzy with weight around 25.8% as shown in Table 8 and Table 9. It is represented graphically in Figure 8.

Table 7
Estimated values for the parameter weights

	Individual Concerns of Stakeholders w_{P1} (%)	**Subjectivity Required** w_{P2} (%)	**Dealing Interdependencies** w_{P3} (%)	**Finding Criticality of NFRs** w_{P4} (%)	**Quantitative** w_{P5} (%)	**Modelling Structure to deal with Interdependencies** w_{P6} (%)
EV	5.3	4.5	31.3	5.3	12.7	40.8
GM	5.3	4.5	31.3	5.3	12.7	40.8

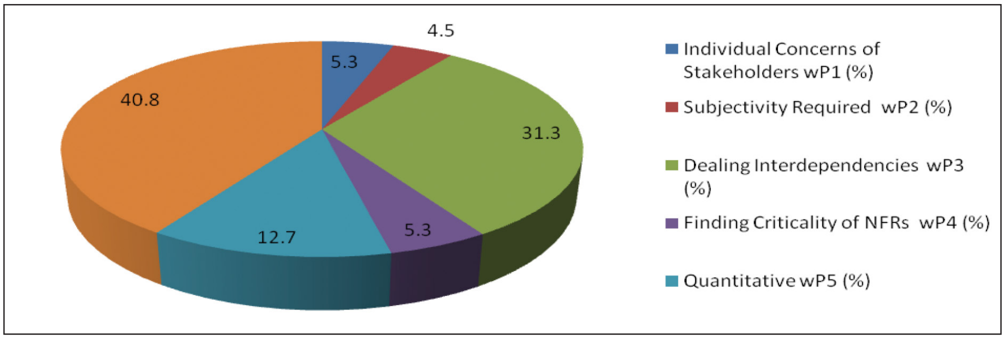

Figure 7. Chart on the basis of weights calculated for different parameters

Table 8

Estimated weights for the available ranking techniques for NFR

		AHP	Fuzzy	Traceability Matrix	Proposed Technique
P1	GM EV	0.25	0..25	0.25	0.25
P2	GM EV	0.25	0..25	0.25	0.25
P3	GM	.117	.223	.082	.578
	EV	.116	.223	.082	.578
P4	GM	.116	.122	.245	.517
	EV	.116	.122	.244	.518
P5	GM EV	.321	.321	.036	.321
P6	GM	.17	.285	.073	.472
	EV	.17	.284	.073	.473
Overall		.177	.258	.098	.467

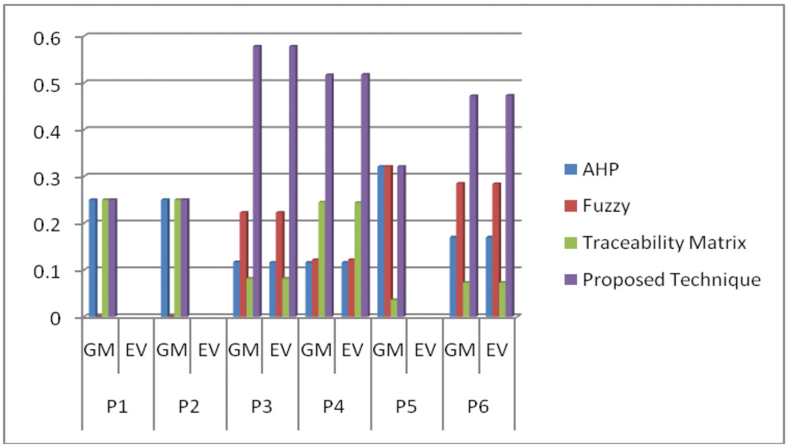

Figure 8. Comparison graph for different trade-off analysis technique

Table 9
Weights suggested by PriEsT for selecting best Trade-off technique

Ranking Techniques	AHP	Fuzzy	Traceability	Proposed
%	17.7%	25.8%	9.8%	46.7

The methodology for finding a suitable procedure is subjective as there can be irregularities in the analysis of the specialists. Such irregularities can be effectively tackled by applying multi-rule technique PrInt on PriEsT tool. Sensitivity investigation is accomplished by taking diverse arrangement of parameters at given time, as shown in Figure 9. The Uniform Distribution view in Figure 9(a) demonstrates Fuzzy and Proposed approach at the same level when viewed on the basis of parameters P1, P2, P3 and P4. Figure 9(b) indicates AHP and Proposed positioning equivalent if contrasted in terms of P3, P4, P5 and P6. Parameter P3 and P6 were weighted as vital parameters as seen in Table 9. At the same point when sensitivity investigation is done on the premise of these parameters, the proposed methodology is considered as the most favoured positioning strategy as shown in Figure 9(c). From the above, it can be concluded that proposed approach supersedes other approaches discussed in the literature on array of parameters and which can be utilised to discover critical NFRs and model their interdependency on each other.

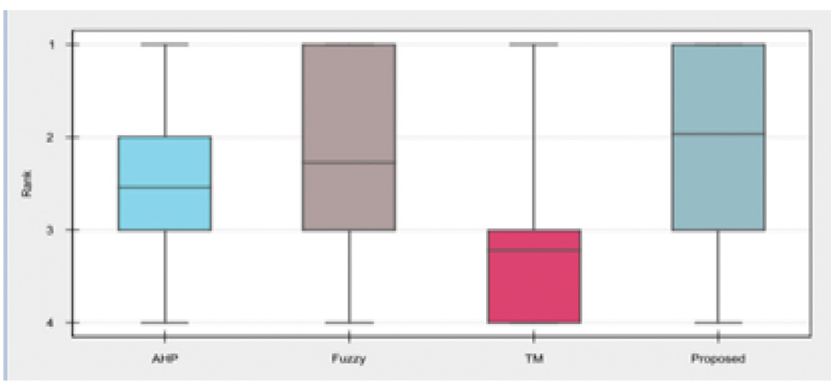

Figure 9(a). Comparison on the basis of parameters P1, P2, P3 and P4

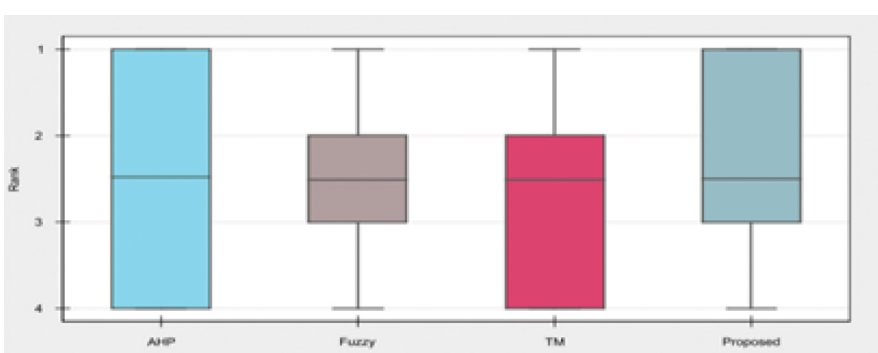

Figure 9(b). Comparison on the basis of parameters P3, P4, P5 and P6

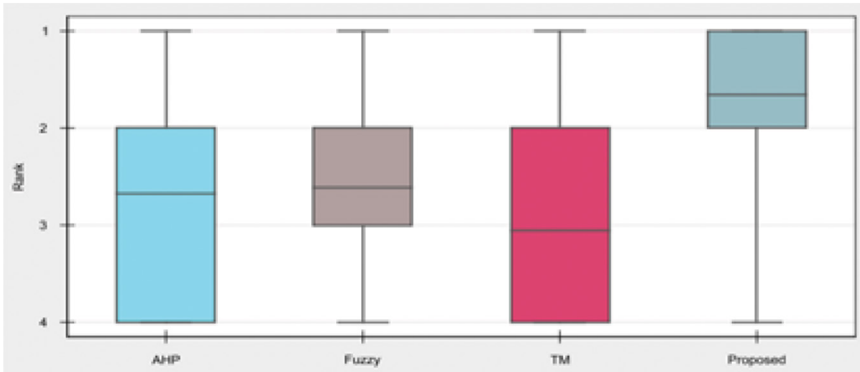

Figure 9(c). Comparison on the basis of P3 and P6

CONCLUSION

Non-Functional Requirements (NFRs) determine the success or failure of a software framework product. As NFR concerns are ordinarily managed at configuration and usage level this methodology often results in the disappointment in the frameworks. Hence, it is good to identify and model suitable NFRs, instead of incorporating them straightaway . A good way is to build up a model that distinguishes critical NFRs from the rest and then look out for potential clashes among them before the prerequisite investigation and analysis. Thus, the most critical non-functional requirements (NFRs) are addressed immediately. The paper proposed a five-step trade off analysis method by using ISM which identified the critical NFRs; dealt with their interdependency by SID; and NFRs classification. The findings of this paper will be greatly beneficial to software development organisations by improving associations involving desired Non-Functional Requirements that will add to programming quality in a financially savvy way.

REFERENCES

Boehm, B. W., Brown, J. R., & Lipow, M. (October). Quantitative evaluation of software quality. In *Proceedings of the 2nd international conference on Software engineering* (pp. 592-605). IEEE Computer Society Press.

Chung, L., & do Prado Leite, J. (2009). On non-functional requirements in software engineering. *Conceptual modeling: Foundations and applications, 5600*, 363-379.

Chung, L., & Supakkul, S. (2004). Integrating FRs and NFRs: A Use Case and Goal Driven Approach. In *2nd International Conference on Software Engineering (SERA'04)* (pp. 30-37).

Digalwar, A. K., & Giridhar, G. (2015). Interpretive structural modeling approach for development of electric vehicle market in India. *Procedia CIRP*, *26*, 40-45.

Elahi, G., & Eric, S. K. (2011). A semi-automated tool for requirements trade-off analysis. In *CAiSE Forum* (pp. 9-16).

Fan, Z. P., & Liu, Y. (2010). A method for group decision-making based on multi-granularity uncertain linguistic information. *Expert systems with Applications*, *37*(5), 4000-4008.

Firesmith, D. (2004). Prioritizing Requirements. *Journal of Object Technology*, *3*(8), 35-48.

Glinz, M. (2007, October). On non-functional requirements. In *15th IEEE International Conference on Requirements Engineering, RE'07, 2007* (pp. 21-26). IEEE.

Grady, R. B., & Caswell, D. L. (1987). *Software metrics: establishing a company-wide program*. Upper Saddle River, NJ: Prentice Hall.

Gunter, C. A., Gunter, E. L., Jackson, M., & Zave, P. (2000). A reference model for requirements and specifications. *IEEE Software*, *17*(3), 37-43.

IEEE. (1993). *Recommended Practice for Software Requirements Specifications* (pp. 830-1993). IEEE Xplore Digital Library.

ISO/IEC 25010:2011. (2011). *Software Engineering - Product Quality - Part 1: Quality Model*. International Organization for Standardization: Geneva, Switzerland.

Jureta, I. J., Faulkner, S., & Schobbens, P. Y. (2006, November). A more expressive softgoal conceptualization for quality requirements analysis. In *International Conference on Conceptual Modeling* (pp. 281-295). Springer Berlin Heidelberg.

Karlsson, J., Wohlin, C., & Regnell, B. (1998). An evaluation of methods for prioritizing software requirements. *Information and software technology*, *39*(14-15), 939-947.

Kassab, M. (2013). An integrated approach of AHP and NFRs framework. In *IEEE Seventh International Conference on Research Challenges in Information Science (RCIS), 2013* (pp. 1-8). IEEE.

Kassab, M., & Kilicay-Ergin, N. (2015). Applying analytical hierarchy process to system quality requirements prioritization. *Innovations in Systems and Software Engineering*, *11*(4), 303-312.

Kaur, H., & Sharma, A. (2016, March). A measure for modelling non-functional requirements using extended use case. In *3rd International Conference on Computing for Sustainable Global Development (INDIACom), 2016* (pp. 1101-1105). IEEE.

Liaskos, S., Jalman, R., & Aranda, J. (2012, September). On eliciting contribution measures in goal models. In *20th IEEE International Conference on Requirements Engineering (RE), 2012* (pp. 221-230). IEEE.

Mairiza, D., Zowghi, D., & Nurmuliani, N. (2010, March). An investigation into the notion of non-functional requirements. In *Proceedings of the 2010 ACM Symposium on Applied Computing* (pp. 311-317). ACM.

McCall, J. A., & Matsumoto, M. T. (1980). *Software Quality Measurement Manual, Vol. II. Rome Air Development Center*. RADC-TR-80-109-Vol-2.

Miller, S. P., & Tribble, A. C. (2001, October). Extending the four-variable model to bridge the system-software gap. In *20th Conference Digital Avionics Systems, 2001, DASC.* (Vol. 1, pp. 4E5-1). IEEE.

Moreira, A., Rashid, A., & Araujo, J. (2005, August). Multi-dimensional separation of concerns in requirements engineering. In *Proceedings of 13th IEEE International Conference on Requirements Engineering, 2005* (pp. 285-296). IEEE.

Mylopoulos, J., Chung, L., & Nixon, B. (1992). Representing and using nonfunctional requirements: A process-oriented approach. *IEEE Transactions on software engineering*, *18*(6), 483-497.

Pressman, R. S. (2005). *Software engineering: a practitioner's approach*. New York, NY: Palgrave Macmillan.

Rao, A. A., & Gopichand, M. (2011). Four layered approach to non-functional requirements analysis. *International Journal of Computer Science Issues*, *8*(6), 371-379.

Roman, G. C. (1985). A Taxonomy of Current Issues in Requirements Engineering. *IEEE computer, 18*(4), 14-23.

Saaty, T. L. (2008). Relative measurement and its generalization in decision making why pairwise comparisons are central in mathematics for the measurement of intangible factors the analytic hierarchy/network process. *Revista de la Real Academia de Ciencias Exactas, Fisicas y Naturales. Serie A. Matematicas*, *102*(2), 251-318.

Siraj, S., Mikhailov, L., & Keane, J. A. (2015). PriEsT: an interactive decision support tool to estimate priorities from pairwise comparison judgments. *International Transactions in Operational Research*, *22*(2), 217-235.

Sommerville, I. (2006). *Software Engineering* (6th Ed.). Boston, MA: Addison-Wesley Longman Publishing Co., Inc.

Wiegers, K., & Beatty, J. (2013). *Software requirements*. United States, USA: Pearson Education.

Yen, J., & Tiao, W. A. (1997, January). A systematic tradeoff analysis for conflicting imprecise requirements. In *Proceedings of the Third IEEE International Symposium on Requirements Engineering, 1997* (pp. 87-96). IEEE.

Zhu, M. X., Luo, X. X., Chen, X. H., & Wu, D. D. (2012). A non-functional requirements tradeoff model in trustworthy software. *Information Sciences*, *191*, 61-75.