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User requirements documentation techniques: a quantitative analysis

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ABSTRACT

User requirements are high-level abstract requirements based on end users and viewpoints of other stakeholders. They are usually written using natural language, occasionally with the help of domain specific models such as mathematical equations, or even informal models not related to any method or language. The purpose of this work is to analyze methods and languages used for user requirements documentation considering a number of criteria. This analysis is performed after extensive literature research and action research at companies that develop software-intensive systems. The objective is not to show how to find the best technique, the one that will perfectly suit all software projects. The assumption is that stakeholders can benefit from knowing which techniques fit better a number of pre-determined evaluation criteria.

Keywords: requirement engineering; analytic network process; analytic hierarchical process; natural language; decision table; use case;

1. INTRODUCTION

Requirements contain descriptions of system properties, specifications for exactly how the system should work, and constraints positioned upon the development process. Software requirements engineering is a well-organized, process-oriented method to the definition, documentation, and maintenance of software requirements in the software development life cycle. Mostly, requirements are statements of what a system must do rather than how it should do it. Requirements for software are a pool of needs expressed by stakeholders respecting constraints in which the software must operate [1, 2]. User requirements are highest, abstract requirements based on end users' and other stakeholders' viewpoint. They are typically written using natural language, rarely with the support of domain specific models such by means of mathematical equations, or else even informal models not associated to any method or language. Poorly written requirement documents often lead to project failures [3]. If the requirement specification has a solid level of quality for a number of identified aspects, the project is further possible to succeed [3]. In many larger firms, there are problems with handling requirements. Requirement documents in altered projects may not have the same setup, language and equal of formalism, for example when using together market-driven requirements and professional requirements. Analysts might quit, taking information with them. Several people or sectors could be working with the same requirements, but in changed systems. Taken together, this means that here is a need to fold the requirements to a solo location and analyze them against all other. Then, the risk is that even if the requirements are written well, they are contradictory. One way of mining and managing requirements that finish format problems and harm of information is to use a software solution. The process by which requirements aimed at systems and software products are collected, analyzed, documented and managed through the development lifecycle is called Requirements Engineering (RE) [4].

Software Requirement Specification is mostly an organization accepting of customer system requirements then dependencies on a specific fact in time preceding to any actual design/development effort. It's a two-way insurance strategy that guarantees that composed the customer and the organization recognize the other's requirements as of that viewpoint at an agreed fact in time. Software requirement specification or requirement documentation is a vital feature of software projects and software engineering (SE). Documentation engineering has developed a recognized sub-domain in the SE culture. The job of documentation in a SE setting is to present collective information to its viewers and instills information of the system it defines [5]. According to [6] an important area of SE is to produce the finest likely occupied software alongside with the best supportive documentation.

The Software Requirement Specification (SRS) is written in exact and clear language based on the functions and capabilities a software system must offer, as well as the restrictions imposed by the system. The SRS provides knowledge for completing a project with as slight cost developments as possible. The SRS is frequently mentioned to

as the "parental" document meanwhile all subsequent project management documents, such as design specifications, announcements of effort, software architecture software specifications, software testing and software validation plans, and documentation plans, are associated to it. Its foremost to note that an SRS includes functional and non-functional requirements; it doesn't deal with design suggestions, probable solutions to technologies or business difficulties, or any extra information rather provides information to development squad that what the client's requirements to be.

An elegant, well-written SRS realizes four main objectives:

It offers reply to the customer. An SRS is the client's guarantee that the development organization recognizes the difficulties to be resolved and the software behavior essential to address those difficulties. Thus, the SRS must be written in natural language in an unambiguous way and strengthen with charts, tables, data flows diagrams, decision tables and so on.

SRS are certainly developed throughout the initial steps of "Requirements Developments," which is the first product development step in which information is composed about what requirements are needed--and not. This information-gathering step can contain onsite official visit, questionnaires, surveys, interviews, and might be a return-on-investments (ROI) analysis of the customer current business environment. The actual specification, at that period, is written after the requirements have been collected and analyzed.

2. LITERATURE REVIEW

Incorrect, misleading, brief, or out of data documentation are some of major attributes which can be liable for poor software quality. Thus, software development companies need to have suitable document control policies. For each software, irrespective of its size and complexity software documentation must be produced. Unfitting generation or omissions of documentation sometimes leads to software failure. Thus, software engineers must pay substantial amount of time focused on generation of software documentation. In this research, we emphasis on the importance of software project documentation.

In a research, 46 methods are examined to create a methodology to select RE techniques [7]. The authors considered a very comprehensive RE context, comparing techniques at dissimilar levels of detail, and with actual different purposes. For instance, they associated Petri nets, interviews, and tests. In another study [8], the authors presented a framework which helps to requirements engineers to choose methods for requirements acquisition. Some higher level common attributes are proposed which can be used for the evaluation and selection of RE techniques in common [9]. In [10], an idea of techniques' selection for requirements elicitation is presented. This technique selection process is built on the human cognitive model.

The researchers have described on the varying landscape of requirements elicitation, analysis, modeling, and verification based on the reported practices in the last decade [11]. The judgment of surveys has revealed some exciting trends including the constant rise of agile methods and their complementary practices. Moreover, certain techniques and paradigms have not dominated yet as expected.

A survey research, on current methods and approaches for consistent composite service area, was conducted to find out how they match with the norms of the proposed framework [12]. A holistic view, on a number of selected techniques, is presented that might be valuable for practitioners when selecting which technique to use precisely for a project [13]. The stakeholders may help to find out which techniques are appropriate based on a number of pre-determined assessment criteria.

In this support, we report the difficult task of requirements prioritization so that the main priority requirements can be implemented as a key portion of the iterative and time-boxed development cycle. Subsequently, defining the meaning of the word "priority", the drive and assistances of requirements prioritization are recorded. This is followed by a short-term discussion of the tasks and threats faced during requirements prioritization. Several techniques for prioritizing requirements are known, and lastly a set of sanctions (with a recommended prioritization process) are complete. A significant problem with prioritizing requirements is that the expression "prioritizing requirements" can have actual different minds to different stakeholders. So let's start by seeing in the dictionary. According to the Merriam-Webster Online Dictionary, the term "priority" means:

1. The formal of being preceding (i.e., given favorite in terms of date or time)
2. Specified or deserving attention before opposing replacements

3. Specified favorite

Although all three of the earlier definitions are closely linked, definition 1 and 2 are very different since meaning 3 in relationship of their influence on, in what way and why requirements are prioritized and in what way the resultant prioritizations are used. The first two meanings deal with scheduling, whereas the third meaning deals with relative importance. And it is not unreasonable to agenda based on more than importance. An additional study in 1998 found a small development: the proportion of effective projects had grown from 16% to 26%, though the proportion of void projects had hardly changed, at 28%. But, there was a affected reduction in the average size of cost and schedule invades for projects in the dared category. The Standish Group attributed a countless deal of the improvement to a main reduction in the typical *size* of projects. For instance, in large companies, the average project size had dropped from $2.3M in 1994 to $1.2M in 1998. Lesser projects are easier to manage, and hence it is relaxed to control costs and schedule.

Outstanding to Requirement Prioritization user attention are enlarged with the project as it authorizes the shareholder to specify those requirements which are of their individual attention. Requirement prioritization also supports to remove the difference among the dissimilar shareholders. Karlsson and Ryan are of the opinion that requirements prioritization propose stakeholders to allocate resources to requirements on the basis of their priorities. Said that requirements prioritization sustenance about the information of the difficulties in the requirements such as mix-up of requirements or some unclear requirement so that it does not reasons problem advanced on [14]. Says that requirement prioritization is very important currently in software development for the increase of projects in order to minimalize the debacle of the developments project [15, 16].

3. PROPOSED FRAMEWORK

3.1 Analytic network process

The Analytic Network Process (ANP) is the enhanced type of AHP and one of the known MCDM (Multi Criteria Decision Making) methods introduced by [17]. The simple structure of the ANP is an effect network of clusters and nodes enclosed inside the clusters [12]. ANP model the inner and outer dependencies among the clusters and clusters elements, i.e. to show inner dependency among the cluster elements and also outer dependency among the clusters. In case of outer influence, there is comparison of influence of the one cluster elements on other cluster elements with respect to some given control criteria. In case of inner influence, the influence of one element on other elements in a group is compared.

According to decision-making structure providing by ANP, the one group elements can be associated with other group elements dependent on the user requirements in order to examine the process to design dissimilar scales. The ANP can be characterized by two networking collections. The first group comprises the criteria and sub-criteria and second group comprises the mutual influence network for the elements which are lying in criteria then sub-criteria groups. This is the aim why the mode of thinking used in ANP is accomplished of mimicking human thinking additional than AHP in decision-making [13, 17].

3.2 User requirements documentation techniques

a) Natural language

The most common method to document user requirements is to write them by means of natural language [18]. The benefits are that natural language is simple and is the key mean of communication between stakeholders. Though, problems such as imprecision, misinterpretations, ambiguity and inconsistency are mutual when natural language is used. As a matter of detail, these problems occur often when natural language is the one means of description of requirements.

b) Structured natural language

Structured Natural Languages are used with the drive of giving more structure to requirements documents. However, structured natural languages are neither formal nor graphical, and can be too much oriented to algorithms and precise programming languages. Other collateral special effects are that structured specifications may limit too initial the programmers' choice to coding.

c) Viewpoint based documentation

Viewpoints are a style for requirements elicitation in which requirements are prepared into an amount of views, giving structure to the procedures of eliciting and specifying software requirements. As it is nearly impossible to recognize all.

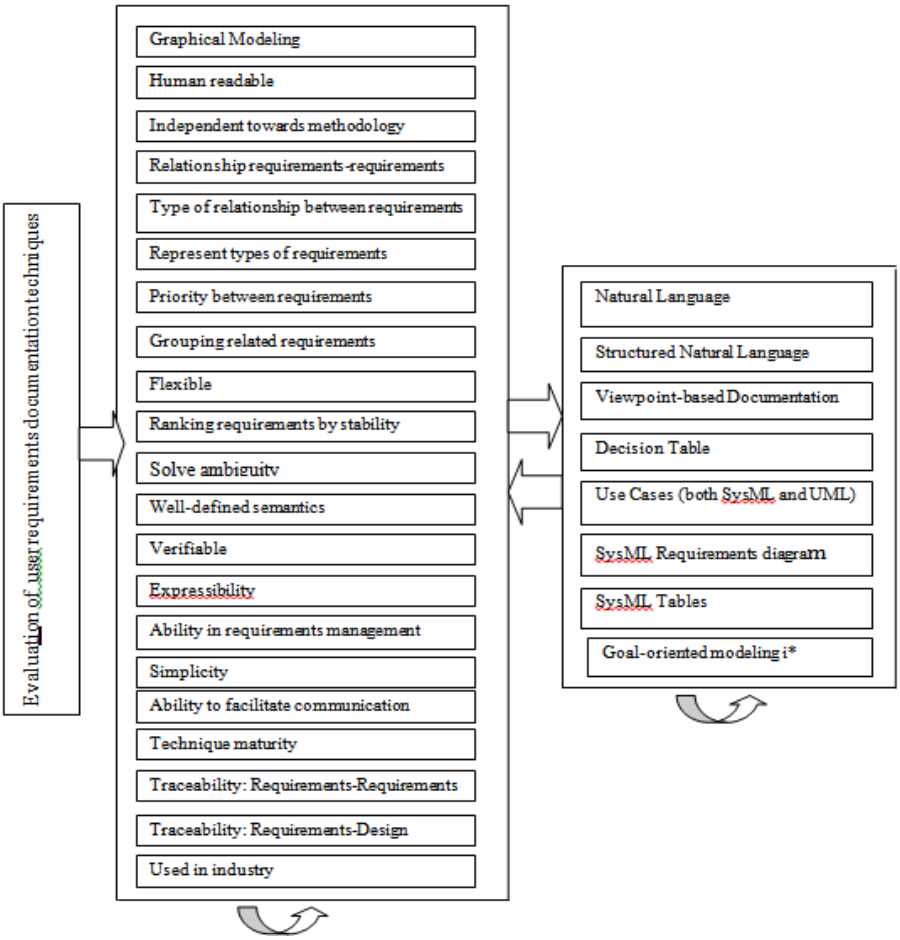

Figure. 1 Analytical network process

Information about requirements seeing only single perspective, it is essential to collect and to establish requirements at a number of different views. The technique is mostly used in industry. Viewpoint analysis is measured as a simple and flexible technique which supports the group of requirements, requirements management, verification of irregularities, and requirements traceability. An important strong point of viewpoint-based documentation is that it knows multiple perspectives and delivers a framework for determining conflicts in requirements proposed by diverse stakeholders. Additional characteristic of viewpoint is that it permits the management of inconsistencies by providing that support to sense and solve them. Typically, every viewpoint provides different kinds of requirements. One problem with viewpoints is that, in exercise, for a high number of recognized viewpoints, it might be difficult to prioritize requirements.

d) Decision table

Decision tables deliver a notation that interprets actions and situations into a tabular format. The table can be used as a machine-readable contribution to a table-driven algorithm. This technique is beneficial when a complex set of circumstances and actions are met within a component.

e) Use cases (SysML and UML)

A renowned diagram used for requirements modeling is the Use Case diagram. Even earlier UML occurred as the key SE modeling language, Use Cases were previously a common practice for graphically representative functional requirements in methodology such as Object-Oriented Software Engineering (OOSE). The fame can be clarified due to their simplicity, making them action as a bridge among technical and business stakeholders. The solid graphical nature is valuable to represent requirements that might be expanded to several pages. Use Cases also have certain disadvantages and problems. They are useful mainly to model functional requirements and are not exactly helpful for other types of requirements, such as non-functional ones. Use Case diagrams lack in precise semantics, which may lead to differences in interpretation by stakeholders. For instance, the <<include>> and the <<extend>> relationships are well-thought-out similar, or even the opposite of each other. In adding, Use Cases may be misrepresented, when too much features are added, which might incorrectly alter the diagrams into flowcharts or make them difficult to realize. User Stories have been used as part of the Xtreme Programming (XP) in agile methodologies. They can be written by the customer using non-technical vocabulary in the format of sentences using natural language. While XP offers some advantages in the RE process in common, such as user participation and defined formats for user requirements and responsibilities, requirements are still roughly related, not graphically specified, and oriented to specific methodologies

- **SysML requirements diagram**

Two SysML diagrams are well-known as useful largely for RE activities: the SysML Requirements diagrams and the SysML Use Case diagrams. One exciting feature of the SysML Requirements diagram is the litheness to model other kinds of requirements also the functional and non-functional requirements. The SysML Use Case diagram is subsequent from the UML Use Case diagram without vital modifications.

- **SysML tables**

SysML tables can be used to characterize requirements in a tabular format. Tabular representations are frequently used in SysML but are not measured part of the diagram classification. Vital decisions on requirements and the writer models are improved and justified when traceability is given proper attention. SysML Tables permit the representation of requirements, their properties and relationships in a tabular format. One way to achieve the requirements traceability in SysML is by using requirements tables.

f) Goal-oriented modeling i*

The attention of goal-oriented modeling moves from what and how (data and processes) as spoke by old-style analysis to who and why (the actors and the objectives they wish to accomplish). Goal-oriented modeling speeches the early analysis or requirements elicitation. i* is one of the furthermost widely used goal modeling languages. Its graphical notation is measured, clear and easy to use and recognize. The strong points of i* are the modest semantics and the graphical notation. The notation provisions the modeling of dependencies amongst actors. These dependencies can be categorized into diverse types. Though, the adoption of i* in industry is still exactly low, even after several years of the introduction of this technique. i* lacks explicit design rationale for its graphical resolutions. Its semantic constructs and grammatical guidelines are well-defined using natural language, which clues to complications of inconsistency, ambiguity, and incompleteness.

3.3 Criteria used for evaluation

The criteria measured for evaluating the techniques and languages used for recording requirements are specified in this section. These criteria are established on interviews with practitioners and researchers, Action Research achieved at companies that develop software, the IEEE Suggested Exercise for Software Requirements Specifications criteria for a worthy requirements document, and traditional textbooks on SE and Requirements Engineering.

- Graphical Modeling
- Human readables
- Independent towards methodologies
- Relationship requirements-requirement
- Type of relationship between requirement

- Represent types of requirement
- Priority between requirement
- Grouping related requirement
- Flexibles
- Ranking requirements by stabilities
- Solve ambiguities
- Well-defined semantic
- Verifiability
- Expressibility
- Ability in requirements managements
- Simplicities
- Ability to facilitate communications
- Technique maturities
- Traceability: Requirements-Requirement
- Traceability: Requirements-Design
- Used in industries

3.4 Research methodology

The concept of interpretivism i.e. truth is socially constructed, there are numerous realties then interpretations and the nature of scientific research is period and context dependent. In this research, multiple approaches will be followed to analyze the different components of framework. This analysis will be carried out through long and argument base discussion with industry experts through online groups, social networks, Skype and physical interviews, about the decision parameters. Survey represents a collective system to gather information in order to explain, define and compare attitudes, knowledge and large populations.

a) Sample selections

Decision-making is done in organizations at executive levels. In this decision-making, considerations are given to different stakeholder's interests. MCDMs are very useful techniques for decision-making. In this study, a proper profiling of relevant organizations is carried out in order to search most relevant people from industry and academia. The main purpose of this profiling is to decrease inconsistency about relativity of different factors.

b) Questionnaire design

The nature of MCDM mechanism is to do direct comparisons between different factors. The aim is to know about the comparative importance of each factor with respect to other factor and so on. To rise the response rate, the size of questionnaire kept short but in direct comparisons, every factor compared with each other factor once and then other comparisons can be derived using transitive property of mathematics. There is also reciprocal property used i.e. a > b three times then b will be 1/3 time small than a. For designing questionnaire and specifying questions, the AHP format was used. In this format, we compare two factors in term of their relative value using five level Likert scales.

4. DATA ANALYSIS

The authority of the Analytic Network Process (ANP) lies in its use of relation scales to capture all types of interactions and make correct predictions, and, even more, to make improved decisions. So far, it has established itself to be a success when proficient knowledge was used with it to expect sports outcomes, economic tries, and business, social and political actions. The ANP is the first mathematical concept that makes it possible for us to contract systematically with all types of dependence and response. The aim for its success is the technique it elicits decisions and uses measurement to derive ratio scales. Priorities as ratio scales are an essential kind of number agreeable to performing the basic arithmetic operations of addition within the same scale and multiplying diverse scales importantly as required by the ANP.

The ANP is a fresh theory that spreads the AHP to cases of dependence and response and simplifies on the Super matrix method introduced in Thomas Saaty's 1980 book on the AHP. It permits interactions and feedback inside clusters (inner dependence) and amongst clusters (outer dependence). Feedback can be improved by capturing the complex effects of interaction in human society. The ANP offers a thorough framework to contain clusters of elements associated in any desired way to investigate the process of deriving ratio scales priorities on or after the distribution

of influence amongst elements and among clusters. The AHP develops a special case of the ANP. Though many decision problems are best considered through the ANP, it is not correct that forcing an ANP model continuously yields better results than using the hierarchy of the AHP. There are illustrations to defend the use of both. We have yet to study when the shortcut of the hierarchies is defensible, not only on grounds of expediency and efficiency, but also for details of validity of the outcome.

4.1 ANP calculation

An Analytic Network Model may consist of a single network or a number of networks. To form an ANP network, you want to:

- Think nearby the elements in it and resolve what type of logical groupings of nodes and clusters would best define the problem.
- Build a cluster first, then make the nodes within it. Choice one node as a potential parental node and scrutinize all the clusters in turn to decide if they have nodes that the parental node either effects or is influenced by to choice its children nodes in that cluster.
- Create the associates between the parental node and completely its children nodes in every cluster – this is how the contrast sets of nodes are created.
- Clusters are connected automatically after nodes are linked.
- Make certain the influences or is influenced by question is stood in a consistent way through this network.
- Make pairwise comparison decisions on nodes and clusters and synthesize.

- **Super matrix**

Every element is signified at single row and one particular column. The additional eigenvector of the sub-elements with respect to their parental element is located to the column on behalf of the parental element and the rows on behalf of the sub-element. There stand three super matrices related with every network: Unweighted Super matrix, the Weighted Super matrix and the Limit Super matrix. Super matrices are established with the clusters in alphabetical order over the top and down the left side, besides by the elements within every cluster in alphabetical order over the top and down the left side. To modify the collation in a Super matrix, one must re-name the clusters and/or the elements, thus their alphabetical order that is derived is the order you want. Altering names after building a model and making differences is allowed and will appropriately preserve any choices that have been made.

Takings a governor criterion. The priorities of the elements resultant from combined comparisons with respect to that control criterion are organized equally, vertically and horizontally consulting to components. The elements in every component are listed meant at that component in a matrix recognized by means of the Super matrix. Respectively, vector occupied as of a combined comparison matrix is portion of the column of the Super matrix representing the effect with respect to the control criterion of the elements of that component on an element of the similar or extra component listed at the top.

- **Weighted super matrix**

If the column summation of one column in the collected super matrix is larger than 1 (there are extra than single eigenvector), that column will be normalized. Such a super matrix is named by way of weighted super matrix. The unweighted super matrix comprises the local significances resultant from the pairwise comparisons through the network. For instance, the significances of the elements Aesthetics and Safety, with respect to Connection A are shown in the two lowest cells of the major column, 0.857143 and 0.142857. This might be interpreted with the statement, "The Aesthetics characteristic of Bridge A is amongst powerfully and very powerfully, or 6 times, additional its main preferred characteristic than its Protection aspect." Altogether the local priority information container be delivered directly since the unweighted Super matrix.

The weighted Super matrix is found by multiplying completely the elements in a component of the unweighted Super matrix through the conforming cluster weight. We will say further nearby cluster weights once we prove the Hamburger model earlier. In this sample, there were no cluster contrasts, then there are only two clusters and cluster contrasts cannot remain complete when there are only two. The weighted and unweighted super matrices are the alike. Notice that as the columns now total to one in the unweighted Super matrix this is not important to weight the components to make the columns sums to single in the weighted Super matrix.

The clusters are completely pairwise matched impacting on a given cluster X with respect to the control criterion. This produces a vector of priorities that effects completely the clusters on a given criterion. Every component of a vector is used to weight completely the elements in the block of column significance of the Super matrix corresponding to the effect of the elements of that cluster on X. The process is common for all the clusters subsequent in a weighted Super matrix.

In every block of the Super matrix, a column is also a standardized eigenvector with possibly some zero entries, or else completely of its elements are equal to zero. In likewise case it is weighted by the priority of the consistent cluster settled the left. If it is zero, that column of the Super matrix essentially be standardized afterward weighting by the cluster's weights. This operation is equivalent to assigning a zero value to the cluster on the left on one occasion weighting a column of a block with zero entries and before re-normalizing the weights of the outstanding clusters.

- **Limit matrix**

The weighted super matrix is powerful in order to have the united or steady values. The values of this limit matrix are the preferred priorities of the elements with respect to the area. The limit of Super matrix is obtained by rising the weighted super matrix to authorities by multiplying it times the condition. When the column of statistics is similar for each column, the limit matrix is achieved and the matrix multiplication process is stopped. The weighted Super matrix is currently column stochastic since which single then originates the limiting Super matrix. There are four main cases to reflect in originating the limit Super matrix liable on the simplicities or multiplicities of the trust eigenvalue and on the reducibilities and irreducibilities of the matrix.

Table. 1 Prioritization of attributes

Attributes	Relative importance	Ranking
Ability to facilitate communication	0.046	1
Traceability: Requirements-Design	0.043	2
Ability in requirements management	0.038	3
Human readable	0.036	4
Simplicity	0.033	5
Independent towards methodology	0.029	6
Graphical Modeling	0.027	7
Grouping related requirements	0.023	8
Used in industry	0.022	9
Traceability: Requirements-Requirements	0.02	10
Expressibility	0.019	11
Verifiable	0.018	12
Well-defined semantics Technique maturity	0.017	13
Techniques maturity	0.017	13
Relationship requirements-requirements	0.017	13
Type of relationship between requirements	0.016	14
Represent types of requirements	0.016	14
Priority between requirements	0.016	14
Ranking requirements by stability	0.016	14
Flexible	0.016	14
Solve ambiguity	0.016	14

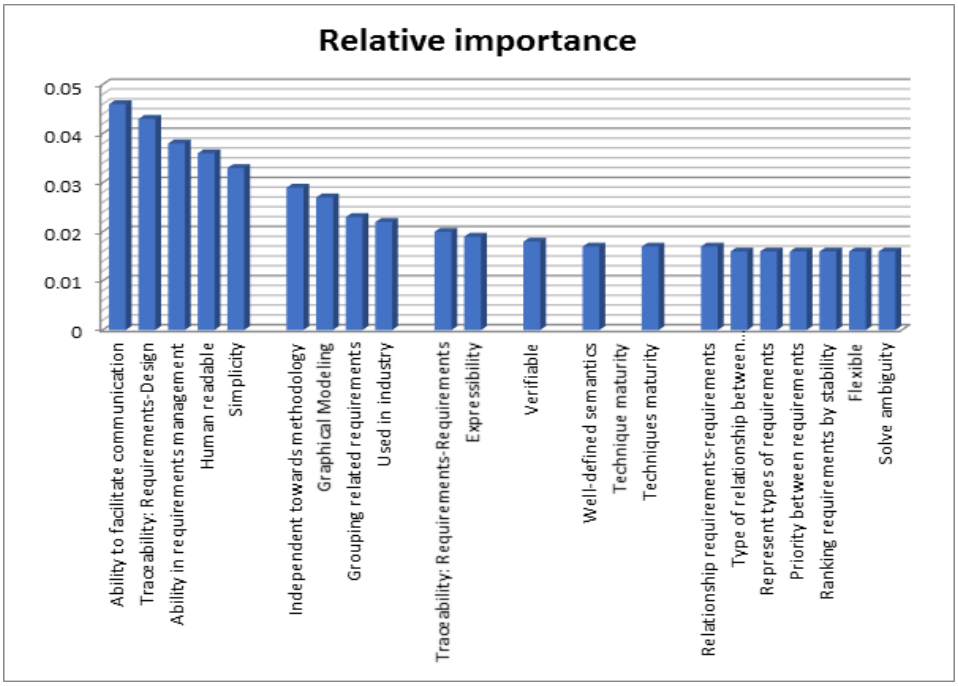

Figure. 2 Graphical representation of priorities of attributes

Table. 2 Prioritization of techniques

Technique	Relative Importance	Ranking
Natural Language	0.074	1
Structured Natural Language	0.058	5
Viewpoint-based Documentation	0.073	2
Decision Table	0.069	3
Use Cases (both SysML and UML)	0.056	7
SysML Requirements diagram	0.057	6
SysML Tables	0.062	4
*Goal-oriented modeling i**	0.052	8

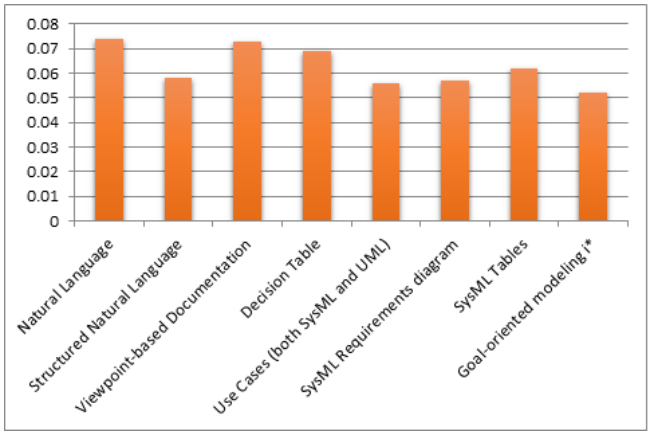

Figure. 3 Graphical representation of prioritization of techniques

5. CONCLUSION

Software documentation is vital piece of software projects and SE. In part of confirmation, documentations engineering has developed established sub-domains in the SE people. The assignment of documentations in an SE environment is to community info to its observers then instills understanding of the system it defines. A number of methods were suggested in previous ages to document user requirements. Selecting the furthermost appropriate single is hard then repeatedly based on ad-hoc result. In command to support the method requirements engineers select, an assessment is required. The determination of this effort is to investigate procedures and languages used for user requirements documentation seeing a number of principles. This study was completed after conducting a wide literature research and action research at corporations that have mature software intensive systems. Hence, it is difficult to discover the best method that best suits to an entire software project. Instead, our determination is to suggest a critical assessment on a number of selected methods that might be valuable for experts when selecting which method to use on a precise plan. The statement is that stakeholders can value from meaningful methods fit to be improved based on a number of pre-determined assessment principles.

The control of the ANP in its practice of proportion scales to capture all types of connections and make precise estimates. Thus, it has confirmed itself to be an achievement when skillful information was used with it to expect good results, economic turn, and business, social and political actions. The ANP is the major scientific idea that makes it likely for us to deal analytically with entire types of dependency and response. The aim for its achievement is the way it elicits findings and uses dimension to arise ratio scales. Priorities as ratio scales are an essential kind of number agreeable to execution the basic arithmetic actions of addition within the similar scale and multiple dissimilar scales expressively as compulsory through the ANP.

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