Section A-Research paper

A METHOD FOR THE IDENTIFICATION AND ANALYSIS OF STAKEHOLDERS OF AN INFORMATION SYSTEM USING FUZZY TOPSIS

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Abstract

Identification of stakeholders and their analysis is one of the key activities of software development process. Despite its importance, it has received less attention during the requirements elicitation process. Based on our review, we found that existing studies do not support the analysis of stakeholders of an information system using fuzzy technique for order of preference by similarity to ideal solution (TOPSIS) and cognitive psychology model. Therefore, to address this issue, a method has been developed for the analysis of the stakeholders of an information system in which verbal protocol technique has been utilized for the collection of data in which subjects were asked to think and understand as they analyze the stakeholders of an information system. The stakeholders of an information system have been classified using fuzzy TOPSIS. The applicability of the proposed method is discussed by considering the stakeholders of an institute examination system. The proposed method has been compared and analysed by two state-of-the-art methods, i.e., StakeRare and StakeSoNet methodologies by using one of the key models of cognitive psychology, i.e., ACT-R model.

Keywords: Stakeholders, StakeRare Method, StakeSoNet Method, Information System, Fuzzy Logic

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1. INTRODUCTION

A stakeholder in an information technology (IT) company is a group of people who can either affect or be affected by the business. The stakeholders of an IT company include investors, employee, customers, developers, testers, requirements modeler, and analyst [1]. Stakeholders can be internal or external to an IT company. Internal stakeholders are those stakeholders whose interest in an IT company comes through a direct relationship like software developers and analyst, ownership, or investment. On the other hand, external stakeholders are those who are directly connected with a company but are affected by their actions and outcomes like consultants, suppliers, creditors, and end users of a system. Successful identification of stakeholders can lead to the development of system for banking sector, university sector, etc. [2].

An information system within an organization capture, stores, and handle information for creating the valuable data which will assist organization and its workers as well as clients. Thus, an information system maintains the information as well as records that play a key role in the success of an organization. A successful information system can only be developed if its stakeholders have been identified and analyzed systematically before the beginning of the requirements elicitation process [3]. Various methods for the identification and analysis of the stakeholders of an information system have been developed like StakeRare [4], StakeSoNet [5], StakePage [6], etc., so that the need of an organization can be fulfilled.

In the literature of software engineering, less attention is given to the analysis of the stakeholders of an information system and most of the focus is on analyzing the functional requirements (FRs) and non-functional requirements (NFRs) of an information system [7], analyzing the use-case and class diagram of unified modeling language (UML) [8], etc. Arif *et al.* [7] analyzed the requirements of an information system using UML and NFR-framework. In their work, the FRs were represented by UML-use-case diagrams, class diagrams, and activity diagrams. The NFRs of an information system were analyzed using NFR-framework. The NFR propagation rules were also derived from the requirements of a library management system. In another study, Siau and Lee [8] investigated the relationship between the use-case and class diagrams using the theories from cognitive psychology. The objective of this study is to analyze

the stakeholders using the proposed method and other two selected methods, i.e., StakeRare and StakeSoNet methodologies and investigate the possible synergic values based on the theories from cognitive psychology. The contributions of our work are as follows:

1. A method has been developed for the analysis of the stakeholders of information system in which fuzzy TOPSIS is used for the classifications of the stakeholders
2. The stakeholders of institute examination system (IES) and library information system (LIS) have been analysed using the proposed method
3. The proposed method has been compared with two state-of-the art method, i.e., StakeRare and StakeSoNet using one of the key models of cognitive psychology, i.e., ACT-R model

The remaining part of this paper is organized as follows: Section II presents a literature review on stakeholders' identification and ACT-R model. The proposed method is discussed in Section III. The experimental work is explained in Section IV. Section V provides the results and discusses the findings. Finally, Section VI concludes the paper.

2. LITERATURE REVIEW

The aim of this section is to present the literature review of stakeholder identification and analysis methodologies and, also discuss a theoretical foundation of ACT-R model. Section 2.1 presents the literature review of two selected stakeholder identification and analysis methods, i.e., StakeRare and StakeSoNet as it has been used in our experimental work. The theoretical foundations and research hypothesis is discussed in Section 2.2.

2.1 An insight into stakeholders' identification and analysis methods

Requirements elicitation is one of the activities of software development in which need of the stakeholders are identified. This activity includes the identification and prioritization of software requirements. Lim and Finkelstein [4] proposed a StakeRare method in which social network and collaborative filtering is used to elicit and prioritize the requirements of large-scale projects. This method identifies the stakeholders and asks the stakeholders to recommend the stakeholders and their roles. The social network of the stakeholders is built in which stakeholders are used as nodes and their recommendations as links. The stakeholders are prioritized using the social network measures to identify their project influence. The StakeRare method was evaluated to a software project having 30,000 user systems. The data was collected after the surveying and interviewing the 87 stakeholders. Based on the experimental work, it was found that StakeRare predicts stakeholders correctly. Motivated by the work of Lim and Finkelstein [4], in 2022, Hassan et al. [5] proposed a StakeSoNet method for the analysis of stakeholders in which social networks was constructed in which stakeholders are represented by nodes and the recommendation of stakeholders by arcs in which linguistic variables were used rather than crisp values for the analysis of the stakeholders. This method includes the following steps: (a) identify the initial set of stakeholders, (b) identify the role of each stakeholder, (c) draw the social network from the selected list of stakeholders, (d) rank the stakeholders based on the social network measures, and (e) classify the stakeholders based on the centrality measures of the stakeholders.

2.2 ACT-R Model

The ACT-R model is grounded on the theory of schemata and scripts, which is used to represent various knowledge structures. The theory of schemata and scripts falls under the dichotomy of propositional-based theories. The ACT model can simulate the operation of any schema using operation set. Siau [9] developed a reference discipline for systems analysis and design research based on cognitive psychology. One of the key models of cognitive psychology is the human information processing model, i.e., ACT-R, which is a revised version of the ACT model [10]. ACT-R model contains the theory of nature of human knowledge and how this knowledge is organized and deployed [8]. This model consists of a goal stack and declarative as well as procedural long-term memory. The ACT-R model is exhibited in Fig. 1. In this study, following hypotheses (H) have been formulated:

- **H1:** The completeness of analysing the proposed method, StakeRare, and StakeSoNet methodologies is different.
- **H2:** The sequence combination of the methods affects the completeness of the stakeholders.
- **H3:** Perceived usefulness is dissimilar among the proposed method, StakeRare, and StakeSoNet methodologies.
- **H4:** Perceived ease of use is dissimilar among the proposed method, StakeRare, and StakeSoNet methodologies.

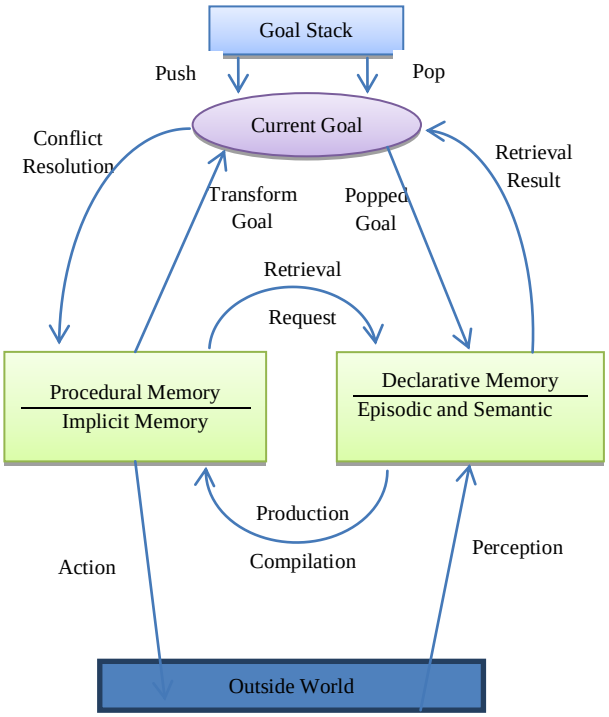

Fig. 1: ACT-R model [8]

3. PROPOSED METHOD

The aim of this section is to discuss the proposed method for the analysis of the stakeholders of an information system. The proposed method includes the following steps:

- **Step 1:** Identification of the stakeholders of an information system based on roles and responsibility
- **Step 2:** Fuzzy based approach for the classification of stakeholders based on the importance of requirements of an information system:
  - **Step 2.1**: Selection of linguistic variables for the decision-making process and
  - **Step 2.2:** Capture the opinions of decision-makers for the requirements
- **Step 3:** Analysis of the stakeholders of an information system using ACT-R Model

The explanation of the above steps is given below:

Step 1: Identification of the stakeholders of an information system based on roles and responsibility

Stakeholders are the main sources of the requirements of an information system. So, before identifying the requirements of an information system, its stakeholders should be identified so that complete list of requirements can be elicited. The aim of this step is to identify the stakeholders based on their roles and responsibility. Roles are responsibilities of the stakeholders are decided based on the need of the project. In this step, the stakeholders are identified based on the types of the functional and non-functional requirements of an information system. For example, in an institute examination system, the stakeholders may be selected based on the roles and responsibility of the types of the goals or requirements, i.e., student's module, administrative modules, and teacher's module.

Step 2: Fuzzy based approach for the classification of stakeholders based on the importance of requirements of an information system

Stakeholder analysis a complex process as it involves various stakeholders and their criteria duirng the software development process. In real life applications, decision makers may use linguistic varaibles to captures their opinion about the stakeholders. Thus, to model the linguistic variables the fuzzy logic has been used in this step.

Step 2.1: Selection of linguistic variables for the decision-making process

Different types of the linguistic variables are used during the decision-making process. Following types of the linguistic variables have been in our work for the analysis of the stakeholders, i.e., Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH).

Step 2.2: Capture the opinions of decision makers for the requirements

The linguitic variables selected in the previous step are used to capture the opinions of decsion makers about the stakeholders so that it can be properly analysed based on the importance of the requirements of an information system. Thus, the aim of this step is to capture the opinions of the decision makers based on their requirements so that stakeholders can be analysed before the starting of the development process.

Step 3: Analysis of the stakeholders of an information system using ACT-R Model

The aim of this step is to analyze the stakeholders using ACT-R model and it includes: (a) research methodology (b) subjects (c) experimental design and (d) data collection methods and data analysis [8].

4. EXPERIMENTAL WORK

The aim of this section is to discuss the steps of the proposed method by considering the stakeholders of an Institute Examination System (IES). The IES is an information system which deals with the examination activities of the students and faculty members of an institute [3].

Step 1: Identification of the stakeholders of an information system based on roles and responsibility

In this step, the stakeholders of an IES have been identified based on the roles and responsibilities. The key list of the stakeholders of an IES is given below:

- **Director:** The role of this stakeholder is to discuss the need of the automation of the examination activities so that students can complete their examination activities without visiting several times in the Office of the Controller of Examinations of an Institute, for example, submitting the examination form of end semester examination, information about the examinations, i.e., date sheet, etc. The responsibility of this stakeholder will be to start the development process based on the consensus of the faculty, students, and other members of their Institute
- **Development company:** The role of this stakeholder is to develop an IES so that the need of the director and their faculty members and students can be fulfilled. The responsibility of this stakeholder is to select a good team so that correct set of the requirements of an IES can be identified, modelled, implemented, tested, and finally deployed to the customer.
- **Tester:** The role of this stakeholder is to understand the software requirements specification document so that before starting the testing process the entire set of requirements of an IES can understood. The responsibility of this stakeholder is to test each and every requirement of an IES so that the end product should be error free.

Step 2: Fuzzy based approach for the classification of stakeholders based on the importance of requirements of an information system

The aim of this step is to classify the stakeholders based on the importance of the requirements of an IES. In the above step, three key stakeholders have been identified. These stakeholders may have various sub-stakeholders. For example, in a development company, there will be many stakeholders, i.e., requirements analyst, requirements modeler, cost estimation, requirements analysis, developers, etc. Therefore, to deal with large set of stakeholders, in this step fuzzy technique for order of preference by similarity to ideal solution (TOPSIS) have been used. A program in C language has been developed for the classification of the stakeholders in which following set of the linguistic variables is used as an input, i.e., Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH). These inputs are modeled by using the triangular fuzzy number (TFNs). The membership values of these linguistic variables are exhibited in Fig.1. In Fig 1, $\mu S\,(\,x\,)$ represents the memberhip value (μ) of the set S for element x. The opinions of the decision makers are captured and as used an input in the C program so that fuzzy TOPSIS can classify the stakeholders of an IES. Based on the classification of stakeholders we found that director of an institute has high influence and high interest in the project. Developers have low influence and high interest in the projects; and the students or end users have low influence and low interest in the project. Such type of classification helps the requirements analyst during the selection and prioritization of the requirements of an information.

Step 3: Analysis of the stakeholders of an information system using ACT-R Model

In this step, the questionnaire and process-tracing method have been applied for experimental work. It

has been observed that the data captured through process-tracing technique is much richer than data captured from input-output analysis [11]. These subjects were asked to fill up questionnaires on the usefulness of the proposed method, StakeRare method, and StakeSoNet methodologies.

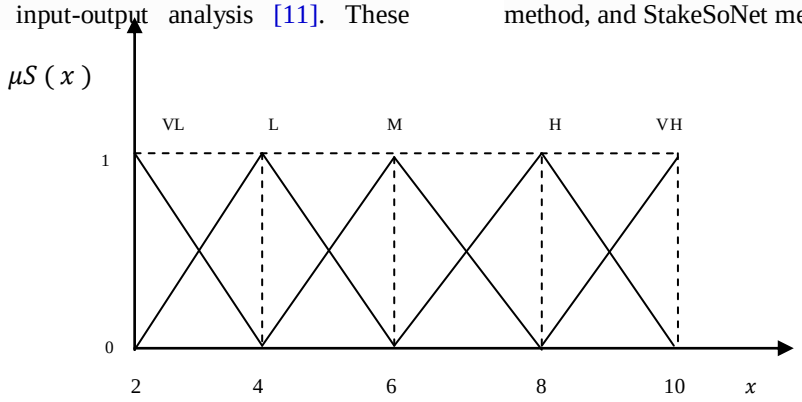

Fig. 1: Membership functions of linguistic values for the classification of stakeholders of an IES

3.1 Subjects

The subjects were the students of Jamia Millia Islamia, New Delhi, India and trainee students of the Indraprastha Institute of Information Sciences Private Limited New Delhi, India, who has completed at least one course of software engineering and software development. Thirty students were invited to participate in the experimental work. These subjects were randomly allocated to one of the two treatment groups during the experiment. In this study, 30 subjects were used for the analysis of data.

3.2 Experimental Design

In the experimental design, both dependent and independent variables have been identified for analyzing the stakeholders of an information system. Table 1 exhibits the experimental design. In Table I, domain 1 is based on institute examination system (IES) and domain 2 is based on library information system (LIS). Here, PM stands for proposed method, SR stands for StakeRare method, and SN stands for StakeSoNet method. The independent and dependent variables used in this study are given below:

- Independent variables: Proposed method, StakeRare method, StakeSoNet method and all the methods
- Dependent variable: Subject's performance for analysing the stakeholders by these methods.

Table I: Experimental Design

Treatment	Domain	
	Domain 1 (IES)	Domain 2 (LIS)
Treatment No 1	Sequence 1: SR→SR+PM	Sequence 2: SN→SN+SR
Treatment No 2	Sequence 2: SN→SN+SR	Sequence 2: SR→SR+PM
Treatment No 3	Sequence 3: PM→PM+SN	Sequence 3: PM→PM+SR

3.3 Data Collection Methods and Data Analysis

The subjects were asked to express their findings using verbal protocol analysis [11]. The verbal statements of the subjects were the key source of data collection and successive analysis. The experimental session was recorded, coded, and analyzed. The recorded data was copied to MS word format and itemized. The itemized amount of information was coded against a listing of information identified by the proposed method, StakeRare and StakeSoNet methods. This listing was formed based on the case analysis of the original source and verified by two experimented software requirements analyst. The recorded pieces of information were counted, calculated, and normalized to enable a consistent comparison of the final data scores.

3.4 Task Domain

Two problem domains have been used in the experiment work. Problem domain-1 was a system analysis of an IES; on the other hand, problem domain-2 was a system analysis of a LIS. The stakeholders of these two systems were adopted from the existing published materials to impose internal reliability of the experimental design. The problem domain-1 was adopted from the work of Sadiq and Devi [12] published in IETE Journal of Research, Taylor and Francis in 2021. The problem domain-2 was adopted from the work of Arif *et al.* [7] published in International Journal of Information Technology, Springer, in 2022.

3.5 Perceived Usefulness and Perceived Ease of Use

In this paper, two determinants have been used during the experimental work, i.e., "*perceived usefulness*" and "*perceived ease of use*". The perceived usefulness refers to the propensity of the

people that the system that they are using will help to accomplish their job better [13]. It can also be defined as "*the degree to which a person believes that using a particular system would enhance his or her job performance*" [13, p, 320]. On the other hand, the perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort" [13, p. 320]. Subjects were requested to answer the questionnaire reflecting their responses on perceived usefulness and perceived ease of use for the proposed method, StakeRare method and StakeSoNet method, at the end of the experimental session. The responses of the subjects based on ''perceived usefulness'' and ''perceived ease of use'' were captured using seven-point scale, where 1 = "*strongly agree*", 2 = "*moderately agree*", 3 = "*slightly agree*", 4 = "neutral", 5 = "slightly disagree", 6 =moderately disagree", and 7 = "strongly disagree".

The perceived usefulness comprises of five questions and it is given below: (a) accomplishes stakeholders' analysis more quickly, (b) improves requirements elicitation process, (c)deals with the linguistic variables, (d) elicit complete set of functional and non-functional requirements of an information system, and (e) makes it easier to do requirements analysis. The questions for perceived ease of use are given below: (a) easy to identify stakeholders of an information system (b) easy to understand, (c) stiff and strict to understand, (5) easy to remember how to do stakeholders analysis, and (6) easy to use.

5. RESULTS AND DISCUSSION

The final data was acquired from counts of matching information elements elicited by 30 subjects during the protocol analysis. These counts were then normalized and used as a single count for the respective method, i.e., proposed method, StakeRare method or StakeSoNet method. The percentile of information counts was normalized per method and used as an input during the statistical analysis. The analysis of variance (ANOVA) and T-test have been employed for statistical testing.

The aim of ANOVA test is to identify if there is any statistical difference between two groups using variance or not. On the other hand, T-test is used in hypothesis testing for comparing the means of two groups. This testing determines whether a treatment has an "effect on the population of interest" or "whether two groups are different from each other." Table 2 summarizes the results of hypothesis testing.

5.1 Effect of the diagram type analysis

The analysis of the outcome of the methods on the completeness of stakeholders of an information system was done using an ANOVA analysis, and it designates the statistical difference ($0.000 < p < 0.001$). This means that there is a substantial difference between two methods types. Hence, the result supported the hypothesis H1: The completeness of analyzing the StakeRare and StakeSoNet methodologies is different.

5.2 Effect of the diagram type analysis

In this section, we discuss the effect on the combination of StakeRare (SR) method and StakeSoNet (SN) method. In sequence 1, StakeRare method is used first for the analysis of the stakeholders then the combination of StakeRare method and proposed method is used for the analysis (SR→SR+PM), on the other hand, sequence 2 use the StakeSoNet first then the combination of StakeRare method and StakeSoNet method is used for the analysis of the stakeholders (SN→SN+SR). The ANOVA test is employed to analyze the effect of sequence combination. As a result, we found that there is an insignificant difference of 0.765 ($p > 0.05$). Hence, the hypothesis H2: the sequence combination of SR and SN affects the completeness of the stakeholders understanding is not supported. The same procedure was applied with the proposed method and StakeSoNet and StakeRare methods.

Table II: Results of hypothesis testing

Hypothesis	*p*-value	Supported
H1	< 0.001	Y
H2	> 0.05	N
H3	> 0.05	N
H4	> 0.05	N

5.3 Perceived usefulness and ease of use

Based on our analysis, we found that there is no statistical difference between StakeRare method and StakeSoNet method for perceived usefulness. This does not support hypothesis H3. Perceived usefulness is dissimilar between StakeRare and StakeSoNet methodologies. We also found that there is no noteworthy difference in the perceived ease of use between the StakeRare and StakeSoNet methods. In this case, the ANOVA test shows the value of 0.413 at $p$level> 0.05. Hence, hypothesis H4: perceived ease of use is dissimilar between the StakeRare method and StakeSoNet method is not supported. In other word, the subjects perceived both proposed method and selected methods, i.e., StakeRare method

and StakeSoNet methods, are useful in analyzing the stakeholders of an information system. Only proposed method supports the classification of the stakeholders based on the salience of the requirements under fuzzy environment.

6. CONCLUSION

This paper presents a method for the analysis of the stakeholders of an information system in which fuzzy TOPSIS method has been employed so that stakeholders can be classified based on the importance of the requirements. The proposed method includes the following steps: (a) identification of the stakeholders of an information system based on roles and responsibility, (b) fuzzy based approach for the classification of stakeholders based on the importance of requirements of an information system, (c) analysis of the stakeholders of an information system using ACT-R Model. Based on our analysis, we found that proposed method, StakeRare and StakeSoNet methods analyze the stakeholders differently. In StakeRare method, crisp values are used for the analysis of stakeholders; on the other hand, the linguistic variables are used for the recommendation of stakeholders in StakeSoNet. In this study, the sequence combinations of the proposed methods with other methods have also been analyzed.

Based on the analysis, it is found that the proposed method classifies the stakeholders based on the importance of the requirements using fuzzy TOPSIS; and there is no support of the classification of stakeholders based on the importance of requirements in the case of StakeRare and StakeSoNet methods. It is also found that there no difference between perceived usefulness and perceived ease of use between StakeRare and StakeSoNet methods. In future, we shall focus on the inclusion of StakePage method for the analysis of the stakeholders of an information system and perform the experimental work with the proposed method, StakeRare and StakeSoNet methods.

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