A PROBLEM ANALYSIS METHOD BASED ON SOFT SYSTEM METHODOLOGY IN REQUIREMENTS ENGINEERING PROCESS

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ABSTRACT

In order to perform Requirements Engineering (RE) process effectively and to extract the correct requirements, it is important to call the requirements engineers' attention to the benefits of focusing on the problem to be solved instead of directly moving to writing requirements from problem definition. However despite of the importance of problem analysis phase, it is difficult to find an appropriate method for performing problem analysis; hence novice requirements engineers find it difficult to perform problem analysis phase. This paper therefore focuses on the proposal of a method for performing problem analysis in RE based on the idea of Soft System Methodology (SSM). The proposed method used different RE techniques such as goals, scenarios, viewpoints etc along with SSM to make the process effective and easier to be used by novice requirements engineers. A prototype tool was also developed to automate the steps of the method. The application of method was shown by applying it on a case study. Finally the method was evaluated by the lecturers having experience of teaching RE course and researchers doing RE research through expert review method and evaluation results showed the positive acceptance of method by experts.

Keywords: *Requirements Engineering, Problem analysis, Soft system methodology.*

1 INTRODUCTION

Software requirements define the services that intended system should deliver and set out limitations on the intended system's operation [1]. A requirement is a statement of some class of user's or other stakeholder's need [2]. Many problems arise with these requirements such as the real needs of customers are not depicted by requirements, incomplete and/or inconsistent presentation of requirements, it is expensive to make changes to agreed requirements, there are misunderstandings between customers, requirements engineers and software engineers who have responsibility of developing and maintaining the system. The best way to reduce these problems is to improve the processes of eliciting, understanding, structuring, validating and managing system requirements [1]. Doing requirements well takes time, effort, and skills at the start of a project, but saves much more time later [2]. Very few organizations have an explicitly defined and standardized Requirements Engineering (RE) process. They simply define the result of process, namely requirements document. The people involved in the process are responsible for deciding what to do and when to do it, what information they need, what tools they should use, etc. [1]

In order to perform RE process effectively and to extract the correct requirements, it is important to call the requirements engineers' focus to the advantages of considering the problem to be solved instead of directly moving to writing requirements from problem definition. Yet without a means to discuss and inquire about problems in a precise, structured way, one can hardly be faulted for skipping problem analysis and leaping straight to the comforting rigor of design. Problem analysis is reported as an important aspect of RE by many researchers such as [3-7]. Methods and approaches that claim the title of 'problem analysis' usually prove, on closer inspection, to deal entirely with putative or outline solutions. The problem to be solved is neither stated in full detail nor explicitly analyzed; the reader must infer the problem from its solution [8]. User may not be able to imagine a new system or how they would use it, but they know what their problem is, and why they would like it fixed. They are expert in their own problem. [2] Experienced requirements engineers can perform the problem analysis using traditional RE methods with the help of their experience and observation. However the problems arise for beginners who have no experience of working on RE projects. It is very difficult for them to perform the activity without an appropriate method. A problem analysis method was therefore needed to be made

available to help novice requirements engineers in performing the process. This paper therefore focuses on the proposal of a method for performing problem analysis in RE based on the idea of soft system methodology (SSM) to be used by the novice requirements engineers. The application of method was presented through a case study. A prototype tool was developed to automate the steps of the method. Finally the method was evaluated through expert review method. It is expected that the proposed method will provide the explicitly defined RE process to perform the problem analysis process to novice requirements engineer.

In section 2 of the paper, background of the study is presented. In section 3 techniques used in the method are presented. Section 4 presents the proposed method. Section 5 presents the screen shots of prototype, section 6 presents the case study on which method was applied, Section 7 presents the evaluation of the method, and section 8 concludes the paper.

2 BACKGROUND

Problem is a situation where someone wanted something to be different from how it is and is not quite sure how to go about in making it so [9]. In RE, we are interested only in finding out the shape of the problem, not in how that problem will one day be solved [2]. The solution for the problem must come after the problem has been identified, documented, understood, and agreed on [10]. Problem reported by users can often be turned around into requirements. [2]

In RE, problem analysis is not explicitly performed but thought to be covered during requirements analysis phase using requirements analysis techniques such as goal-based requirements analysis methods, scenario-driven requirements analysis methods, structured Analysis and design methods, viewpoint analysis methods, object-oriented analysis methods etc. However requirements analysis methods should be used after some initial elicitation has been carried out. Problem analysis in RE covers initial understanding of the problem as well as analyzing and structuring the requirements. The two phases covered by problem analysis in RE are:

- Identifying what the problem really is or what the customer requires, and
- Refining and specifying the requirements on a desired system.

The structured methods of requirements analysis through which these two phases of problem analysis are normally thought to be performed, are not particularly useful for early stages of analysis where application domain, the problem and the organizational requirements must be understood. They are based on hard models of system, such as entity relationship models, data flow models etc. These models are inflexible and focus on automated systems. [11]

By contrast, soft systems methods can help in initial phases of software development as they rely on producing less formal models of the whole socio-technical systems. Soft System Methodology (SSM) is the best known of these approaches. SSM was not specifically designed as a technique of eliciting requirements for computer-based systems. Rather, it was developed to help apply 'system thinking' to problems within organizations. This perspective makes the approach usable in requirements elicitation. [11] Therefore it is proposed to use the concept of SSM for performing problem analysis in RE. SSM is briefly described in the following subsection.

2.1 SOFT SYSTEM METHODOLOGY (SSM)

SSM provides a means to understand abstract system requirements by analyzing organizational context, the problem to be solved and existing systems which are in place. SSM is more effective for helping to understand a problem, the organizational situation in which the problem exists and the constraints on the problem solution. [11]

SSM emphasizes on problem identification, problem structuring, and problem resolution, rather than on problem solution. SSM acts well when solving problems concerning complicated, interacting and dynamic group of processes in a situation, where a change is wanted to carry out somewhere in this continuum of processes. This is made by comparing the present real world situation of the system with those models of the system that are thought to make the system work in a more practical way. The seven stages of SSM are presented in Fig. 1.

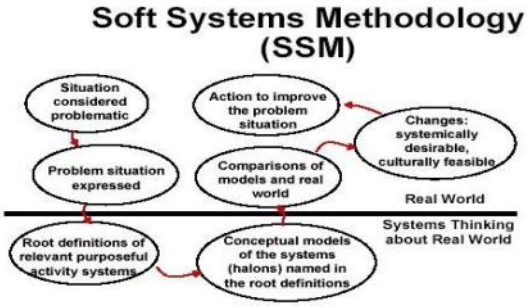

Fig. 1 The stages of SSM [12]

In SSM, systems thinker can look at an aspect of the world from a number of different viewpoints. The use of viewpoints can provide a better chance of discovering the

requirements. Some viewpoints that are particularly useful are listed here:

- How it is: the view of the world you are trying to understand
- What it is: the view of the meaning or the essence behind how things are done
- What it will be: the view of how things will work in the future, or the product you plan to build. [13]

3 TECHNIQUES USED IN THE METHOD

The proposed method used different RE techniques along with SSM to make the process effective and easier for novice requirements engineers. The selected techniques are presented below:

- SSM is selected as a front-end method because:
  - It is useful for the early stages of analysis. It is more effective for helping to understand a problem, the organizational situation in which the problem exists and the constraints on the problem solution. They produce abstract requirements for a system which need to be flashed out using other techniques [11].
  - The systems thinking approach that is, SSM, can be effectively used in requirements analysis. It provides techniques for observing and modeling the world for the purpose of understanding and tackling real-world problems. [13]
- The use of goals and scenarios in problem analysis. The goal-scenario combination is proved to be very effective for addressing different problems. Many researchers proposed to merge goals and scenarios together in order to overcome deficiencies of goal-driven and scenario-based approaches when used in isolation [14-18].
- The use of viewpoints for requirements analysis. Viewpoints are considered an efficient way to discover requirements from different perspectives, and can be proved more useful if combined with goals and scenarios.

4 TOWARDS A PROBLEM ANALYSIS METHOD

The proposed method consists of following elements:

- One should at least have general understanding of the application domain and the problem to be solved [11]. Therefore it is suggested that the user should have two inputs prior using our method that are: Customers' needs (initial informal problem statement of the customer) and Application domain knowledge (background knowledge of the area under study).
- In requirements analysis it will be easier for analyst to look at an aspect of world from a number of different viewpoints [13]. Therefore, concept of SSM is transformed into two main viewpoints:
  1. **What it is:** the view of the world you are trying to understand (real world thinking)
  2. **What it will be**: the view of how things will look in future, or the product you plan to build (System thinking)
- While the CATWOE (Customers, Actors, Transformation process, world-view, Owner (s) and Environmental factors) transformation (from SSM) will show that what needs to be changed (from first perspective) into what (from second perspective).

These ideas are depicted in Fig. 2.

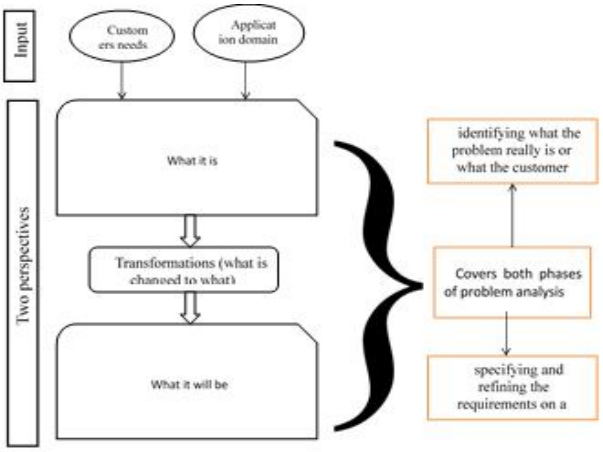

Fig. 2 Main elements of the proposed method

These three elements are presented in detail in the following subsections.

4.1 THE FIRST PERSPECTIVE: WHAT IT IS?

This is about understanding what the customer's problem really is. The activities performed in this perspective are presented at the left side of Fig. 3, while explanation and technique used to perform each activity are described at the right side of Fig. 3.

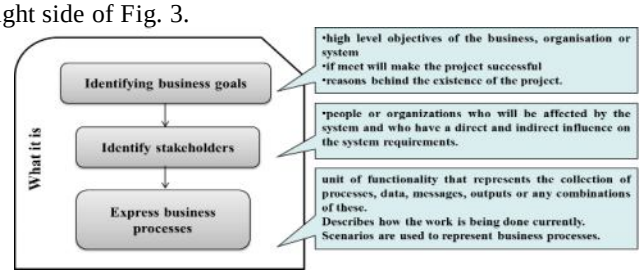

Fig. 3 The first perspective

From customer needs and application domain knowledge (inputs), the business goals and stakeholders are identified. The main step of this stage is identifying and expressing the business processes. These processes depict the way the work is done in the organizations and it is assumed that the problem occurs due the way these processes are currently performed; therefore steps in each business process are described in detail so that the problems can be identified.

4.2 TRANSFORMATIONS (WHAT IS CHANGED TO WHAT)

In this stage, each business process is analyzed in detail to identify the problem or the feature that needs to be changed to address the problem. This detailed analysis is performed through CATWOE analysis. CATWOE describes how the business processes are transformed into system processes and why.

CATWOE is a mnemonic for:

- Customers (and other stakeholders), i.e. people who are affected by transformation.
- Actors, i.e. the people who perform the activities in the transformation.
- Transformation process, stating what is changed and to what.
- World-view or perspective from which the transformation is meaningful.
- Owner(s), i.e. the person or people who control the transformation.
- Environmental / external factors, i.e. anything that constrains the transformation.

4.3 THE SECOND PERSPECTIVE: WHAT IT WILL BE?

It includes identifying the real requirements of the customer and refining those requirements. The activities performed in this perspective are presented at the left side of Fig. 4. While the explanation and technique used to perform each activity are described at the right side of Fig. 4.

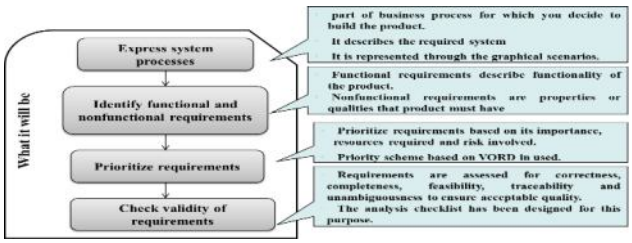

Fig. 4 The second perspective

In the first step of this stage, the system processes are described in detail. The transformation from business to system process is the key of the proposed method and the changes required to transform the business into system process are the requirements of the software. Therefore from system process the functional as well as non-functional requirements are identified. Functional requirements are what the user need for the system to work. Nonfunctional requirements are global, fuzzy factors or principles that relate to the system's overall success. [10]

The next two steps of the stage that is, prioritize requirements and check validity of requirements, are performed to refine the identified requirements. The priority scheme for calculating the priority of each requirement (based on [19]) is presented in table 1.

Table 1. The priority scheme

Weighing Factor	High (H)	Medium (M)	Low (L)
Importance	3	2	1
Resources required	1	2	3
Risk involved	1	2	3

The validity of requirements is checked using analysis checklists. The analysis checklist to validate each requirement is presented in table 2.

Table 2. Analysis checklist for individual requirement

1.	Is the requirement uniquely and correctly identified?
2.	Is the requirement in scope for the project?
3.	Is any necessary information missing from a requirement?
4.	Is the requirement as modifiable as possible?
5.	Is the requirement written in clear, concise, unambiguous language?
6.	Is the requirement free from content and grammatical errors?
7.	Is the requirement written in the customer's language, using the customer's terminology?
8.	Is the requirement acceptable to all stakeholders?
9.	Is the requirement a statement of stakeholder need, not a solution?
10.	If appropriate, is the requirement traceable?

4.4 THE PROPOSED METHOD

All elements presented from section 4.1 – 4.3 are combined to present the complete method (Fig. 5). Techniques used to perform each activity of the method are presented through cloud symbol.

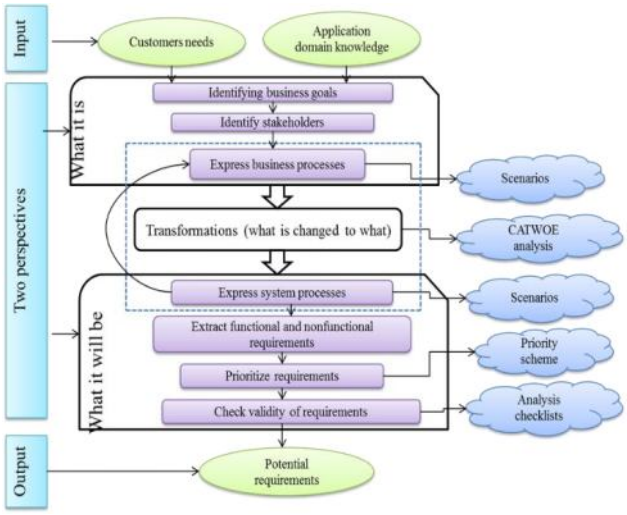

Fig. 5 The proposed method

The output of the method are potential requirements that are presented using requirements name, description, type and priority.

The proposed method is applied to a case study "Hospital management System" to show its application. A few steps of method application (until requirements extraction) of a few business processes are presented in section 6. In order to automate the process of the method, a prototype is developed using dot net framework. SQL server is used to design the back-end database.

5 A PROTOTYPE TOOL BASED ON PROPOSED METHOD

A prototype tool was developed based on the method in order to automate the steps of method. A few screen shots of the tool are presented in the section.

Fig. 6 presents the main screen of the tool. The steps of the method are shown at the left side of the screen.

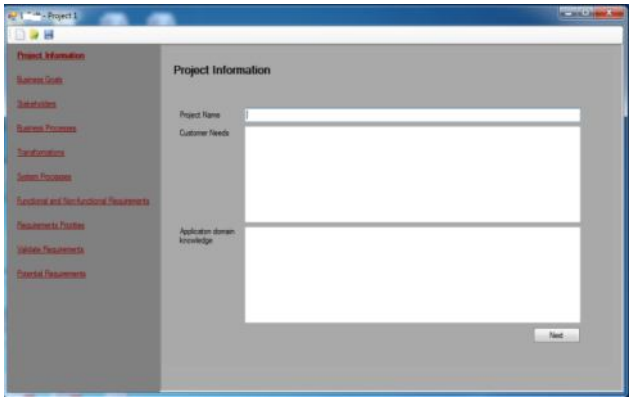

Fig. 6 Screen shot of main screen

Fig. 7 shows the screen shot of the page that ask the user to enter the stakeholders' information.

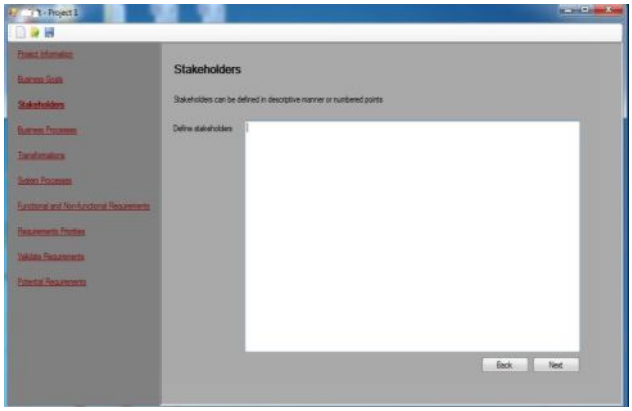

Fig. 7 Screen shot of stakeholders screen

Fig. 8 shows the screen shot of the page that allows the user to enter the functional/nonfunctional information.

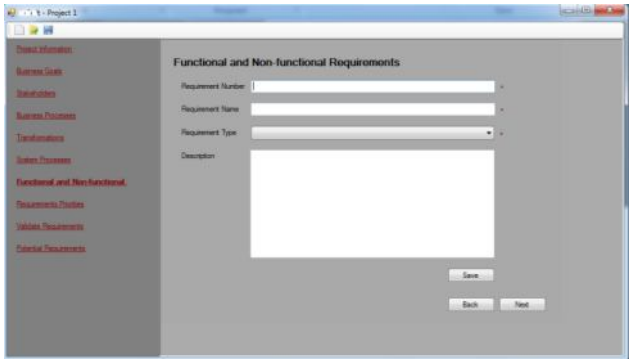

Fig. 8 Screen shot of requirements screen

Fig. 9 shows the screen shot of page that guide user in assigning priorities to the requirements.

Fig. 9 Screen shot of requirements priorities screen

Fig. 10 shows the screen shot of the page that allow the user to validate the requirements using analysis checklists.

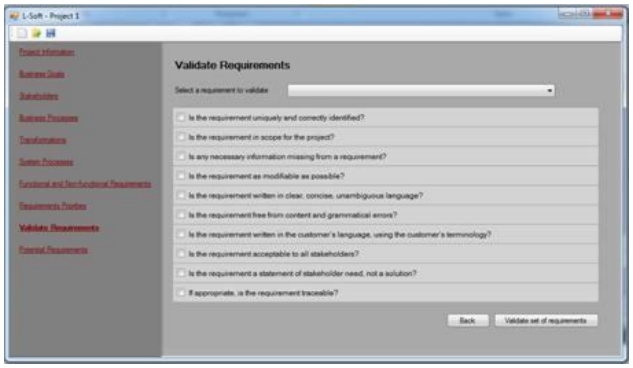

Fig. 10 Screen shot of validation screen

In the last page i.e., 'potential requirements', the set of requirements will be shown along with their associated information.

6 APPLICATION OF METHOD ON A CASE STUDY

The proposed method was applied on a case study to show its application on real world problems. The case study named Hospital Management System (HMS) is presented in the following sections.

6.1 CASE STUDY: HOSPITAL MANAGEMENT SYSTEM (HMS)

Customer needs:
The desired software product is the Hospital Management System (HMS). Currently most of the management operations are performed manually. The customer wants centralized hospital management system software that should be able to perform all the operations, such as system will be used to allocate beds to patients on a priority basis, and to assign doctors to patients in designated wards as need arises. Doctors will also use the system to keep track of the patients assigned to them. Nurses who are in direct contact with the patients will use the system to keep track of available beds, the patients in the different wards, and the types of medication required for each patient. The current system in use is a paper-based system. It is too slow and cannot provide updated lists of patients within a reasonable timeframe. Doctors must make rounds to pick up patients' treatment cards in order to know whether they have cases to treat or not. The intentions of the system are to reduce over-time pay and increase the number of patients that can be treated accurately.

Business goals:
Work Scheduling
Automation of patient's admissions and discharge operations
Automation of management services

Stakeholders:
Administrators: They all have post-secondary education relating to general business administration practices. They are responsible for all of the scheduling and updating day/night employee shifts. Administrators in the wards are responsible for assigning doctors and nurses to patients.
Doctors: All doctors have a medical degree. Some have further specialized training. Doctors will use the HMS to check their patient's list and duties schedule.
Nurses: All nurses have post-secondary education in nursing. Consulting nurses to whom patients give short descriptions of their conditions are also responsible for assigning patients to appropriate wards if the beds are available, otherwise putting patients on the waiting list. Nurses in wards will use the HMS to check their patient list and duties schedule.
Reception staff: They all have general reception and secretarial duties. Every staff has some basic computer training. They are responsible for patient's check-in or notification of appropriate people (e.g. notify administrator or nurse when an event occurs).

Processes:

- Patient registration
- Consultation
- Work scheduling
- Inpatient checkout
- Storing and retrieving information.

The application of first three processes have been provided in sections below.

6.2 PATIENT REGISTRATION PROCESS

Business process
Business process name: Patient registration
Stakeholders: Patient, reception staff

- Patient comes at reception desk and ask for medication
- Reception staff ask patient to fill in the form.
- Patient fills the form.
- Reception staff checks the form.
- Assign patient an identification number (ID) and make ID slip
- Patient receives ID slip.

Transformations:

- Customers: Reception staff, patient
- Actors: Developers, reception staff
- Transformation: From manual patient registration process to computerized registration process

- World-view: Every patient who visits the hospital has to get registered in order to get any consultation, treatment or investigations done.
- Owner: Owner of hospital.
- Environment: Every reception staff should have some basic computer training and should be provided training to operate the software.

System process

The graphical scenario of the required system process is shown in fig. 11.

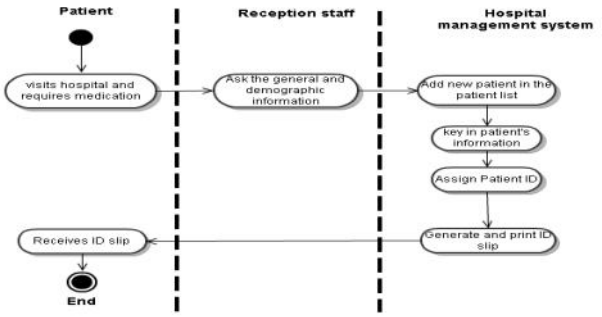

Fig. 11 Graphical scenario of system process of patient registration

Functional Requirements

- **R001 Add patients**

The HMS shall allow reception staff to add new patients to the system.

- **R002 Assign ID**

The HMS shall allow reception staff to give each patient an ID and add it to the patient's record. This ID shall be used by the patient throughout his/her stay in hospital.

- **R003 Assign ID**

The HMS shall allow reception staff to generate and print the registration slip with ID on it.

6.3 CONSULTATION

Business process

Business process name: Consultation
Precondition: Patient must have valid ID
Stakeholders: Patient, consulting nurse

- Patient explain the symptoms
- Consulting nurse checks the patient.
- Based on symptoms, the consulting nurse either refer patient to OPD (Outpatient Department) doctor or admit in the hospital (In Patient).
  - If Outpatient, the appointment is given based on availability of doctor and patient is asked to wait.
  - If Inpatient, nurse checks availability of bed in the specific ward
- If available , patient is admitted immediately
- If not available, the patient is put in the waiting list and admitted once bed is available

Transformation:

- Customers: Patient, consulting nurse
- Actors: Developers. Consulting nurse
- Transformation: From manual to computerized consultation service
- World-view: Consulting nurse do not have to go to the specific ward to check availability of bed, computerized records will help her to perform the process efficiently.
- Owner: Owner of Hospital.
- Environment: All nurses have post-secondary education in nursing; some nurses are computer literate while others should provide some training. Patient must have ID to enable him for consultation.

System process:

The graphical scenario of the required system process is shown in fig. 12.

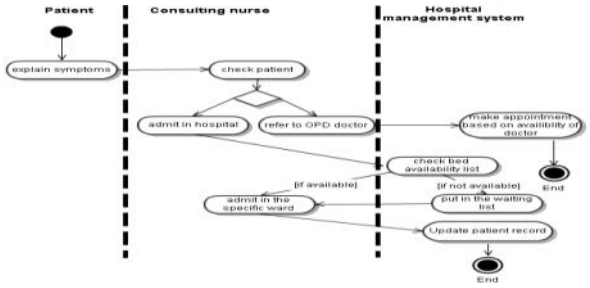

Fig. 12 Graphical scenario of system process of consultation

Functional Requirements

- **R004 make appointment**
  The consulting nurse shall use HMS to access the doctor's appointment lists and make appointments accordingly for Outpatients.
- **R005 Assign Ward**
  The consulting nurse shall use HMS to assign the patient to an appropriate ward.
- **R006 Assign to Waiting List**
  The consulting nurse shall use HPMS to assign Patient to a waiting list if no bed is available.
- **R007 Update patient's record**
  The consulting nurse shall use HMS to update Patient's record.

6.4 WORK SCHEDULING

Business process

Business process name: Work scheduling

Precondition:

Stakeholders: Administrative staff, nurses, doctors, reception staff.

- Administrative staff schedule weekend and day/night duties for doctor and nurses and other staff each week.
- Assign doctors and nurses to each patient
- Schedule surgery cases
- assign surgery room to patient
- Assign surgeon and nurses to patient
- Inform doctors, nurses and other staff about their duties.

Transformation:

- Customers: Doctors, nurses, patients, administration staff
- Actors: Doctors, nurses, patients, administration staff, developers.
- Transformation: From manual scheduling of duties to computerized work scheduling system.
- World-view: Increase efficiency by providing updated lists of patients within a reasonable time frame; doctors do not have to make rounds to pick up patients' treatment cards in order to know their condition.
- Owner: Owner of the hospital.
- Environment: All the staff should be equipped with computers and should be provided with training to use the software.

System process

The graphical scenario of the required system process is shown in fig. 13.

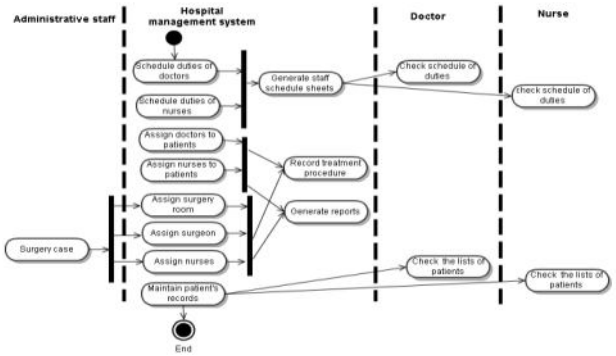

Fig. 13 Graphical scenario of system process of work scheduling

Functional Requirements

- **R008 Schedule Doctor's duties**
  The administrative staff in the ward shall use HMS to schedule day/night and weekend duties of doctors, nurses and other staff and generate schedule sheets.
- **R009 Assign Doctor**
  The administrative staff in the ward shall use HMS to assign a doctor to a given patient.
- **R010 Assign Nurse**
  The administration staff in the ward shall use HMS to assign a nurse to a given patient.
- **R011 Inform Doctors**
  The HMS shall inform doctors of new patients.
- **R012 Inform Nurses**
  The HMS shall inform nurses of new patients.
- **R013 Emergency Case**
  In an emergency case, the administrative staff shall use HMS to assign an emergency room, doctors and nurses to the patient immediately.
- **R014 Surgery case**
  In a surgery case, the administrative staff shall use HMS to assign a surgery room, surgeon and nurses to the patient.
- **R015 Generate Report (normal)**
  The HMS shall generate the patient's situation record every two hours for normal patients.
- **R016 Generate Report (Severe)**
  The HMS shall generate patient's situation record every half hour for severe patients.
- **R017 Record procedure**
  The whole treatment procedure for the patient shall be recorded by the system.
- **R018 Inform patient**
  The HMS shall automatically inform the patients who are on the bed waiting list of available beds whenever they become available.

7 EVALUATION OF PROPOSED METHOD

The preliminary evaluation of the proposed method is performed using expert reviews in order to evaluate the effectiveness of the method for performing problem analysis in RE. This section describes the participants, questionnaire; procedure used and results of the evaluation.

7.1 PARTICIPANTS

The lecturers having experience of teaching RE course and researchers doing RE research were selected as the participants of the study with the expectation that they can better assess the method due to many years of work experience. Total of six experts participated in the study. Of which two are from university of Malaya Malaysia, one from university of Putra Malaysia, one from university of Twente Netherlands and two from Mehran university of Engineering and Technology Pakistan. The average

experience of participants was 10 years of teaching/research.

7.2 QUESTIONNAIRE

The questionnaire included three categories of questions. In the first category, participants were asked to rate the effectiveness of processes of method, that are input, what it is, what is changed to what, what it will be and output of the method. In the second category, participants were asked to rate the applicability of techniques used in the method, that are scenarios, CATWOE analysis, priority scheme and analysis checklist. In the third category perception of experts towards the method were assessed through different questions, such as relevancy of theories and concepts chosen, efficiency of SSM as a front-end method, comprehensiveness of the method, effectiveness of the method etc. The scale used for all the three categories were very high-very low.

7.3 PROCEDURE

The lecturers and researchers from different countries were invited to participate in the study through emails. Those who agreed were sent all relevant documentation of the method including introduction, purpose, method itself, case study and tool setup along with the questionnaire. The responses were received in about one week time.

7.4 RESULTS

The results from first category of questions that are related to effectiveness of processes are presented in Fig. 14.

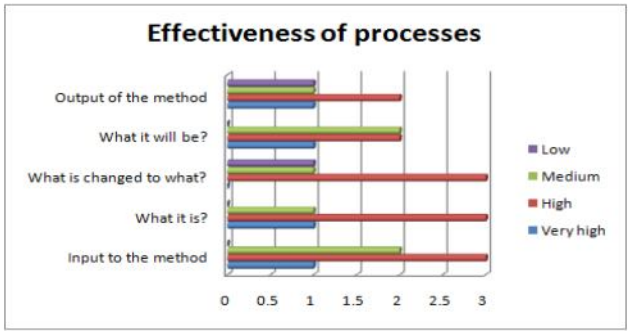

Fig. 14 Results of first category of questions

The results of second category of questions that are related to applicability of techniques used in the method are presented in Fig. 15.

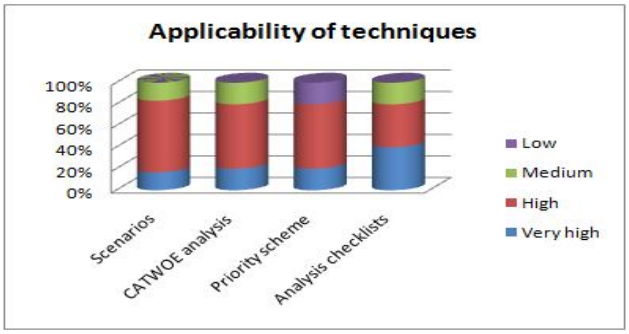

Fig. 15 Results of second category of questions

The results of third category of questions that are related to perception of experts towards method are shown in Fig. 16.

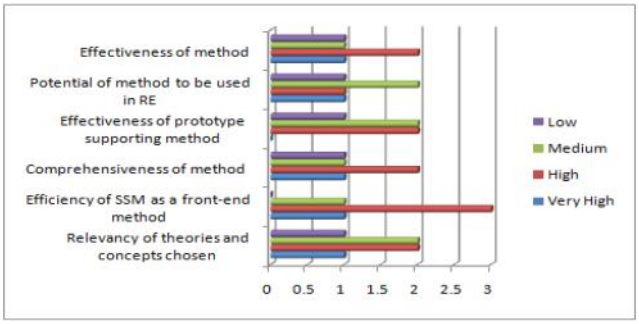

Fig. 16 Results of third category of questions

It can be noticed form the results that most of the experts have shown positive acceptance towards the method. Most of them also agreed with choice of processes and techniques of the method. Therefore it can be concluded that the method have a high potential of being used for performing problem analysis in RE.

8 LIMITATIONS OF STUDY

There are several limitations in this research. The proposed method is aimed at being easy to understand and apply RE method for performing the problem analysis process. However due to the complex nature of RE, one still need to perform a lengthy process and have to master many terms and concepts in order to cover the complete problem analysis process. In addition, the scope of the proposed method was limited to the problem analysis process only. Requirements engineers need to use requirements elicitation activities along with the proposed method in order to successfully apply the method and generate requirements. Also it does not cover complete RE process and needs to be accompanied with other RE processes and techniques.

The proposed method and tool have been developed only to make engineers perform the problem-based projects

(Problem-based projects start when a problem arise that demands a response). The blocking factors in their usage in production are they do not cover the complete RE process, plus they may not applicable to all domains. They only supports problem-based projects but not applicable to other types of projects such as contract-based or game development projects. This can also be seen as a limitation of proposed method.

9 CONCLUSION

The paper presented a method for performing problem analysis in RE to help novice requirements engineers in understanding and performing problem analysis process. The idea of using SSM in RE for problem analysis has been proposed. The method combined the concepts of SSM with RE techniques to improve its effectiveness in RE. A prototype application was developed to automate the steps of the method. The method is also applied to a case study to show its applicability in practice. The preliminary evaluation of the method was performed through expert reviews. However it is strongly needed to evaluate the method in practice by applying it on real projects. Therefore it is intended to perform an experimental validation study to assess its actual applicability and effectiveness in practice.

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