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Requirements Validation Techniques and Factors Influencing them

Santosh Kumar Reddy Peddireddy
Sri Ram Nidamanuri

Faculty of Computing, Blekinge Institute of Technology, 371 79 Karlskrona, Sweden

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The authors declare that they are the sole authors of this thesis and that they have not used any sources other than those listed in the bibliography and identified as references. They further declare that they have not submitted this thesis at any other institution to obtain a degree.

Contact Information:
Author(s):
Santosh Kumar Reddy Peddireddy
E-mail: pesn17@student.bth.se

Sri Ram Nidamanuri
E-mail: nisr17@student.bth.se

University advisor:
Dr. Nauman Bin Ali
Department of Software Engineering

Faculty of Computing
Blekinge Institute of Technology
SE–371 79 Karlskrona, Sweden

Internet : www.bth.se
Phone : +46 455 38 50 00
Fax : +46 455 38 50 57

Abstract

Context: Requirement validation is a phase of software development life cycle where requirements are validated to get rid of inconsistency, incompleteness. Stakeholders involved in the validation process to make requirements are suitable for the product. Requirement validation techniques are for validating the requirements. Selection of requirements validation techniques related to the factors that need to consider while validating requirements makes the validation process better. This paper is about the factors that influence the selection of requirements validation technique and analyzing the most critical factors.
Objectives: Our research aim is to find the factors influencing the selection of requirement validation techniques and evaluating critical factor from the factors list. To achieve our goal, we are following these objectives. To get a list of validation techniques that are currently being used by organizations, and to enlist the factors that influence requirement validation technique.
Methods: To identify the factors influencing the selection of requirement validation techniques and evaluating the critical factors, we conducted both a literature review and survey.
Results: From the literature review, two articles considered as our starter set, and through snowball sampling, a total of fifty-four articles were found relevant to the study. From the results of the literature review, we have formulated a questionnaire and conducted a survey. A total of thirty-three responses have gathered from the survey. The survey obtains the factors influencing the requirement validation techniques.
Conclusions: The factors we got from the survey possess a mixed view like each factor has its critically in different aspects of validation. Selecting one critical factor is not possible during the selection of requirement validation technique. So, we shortlisted the critical factors that have more influence in the selection of requirement validation techniques, Factors, Requirements validation techniques.

Keywords: Requirements validation, Requirements engineering, Factors, Requirements validation techniques.

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"From the depth of our heart, we are grateful for their adulation and guidance at every step, thanks to our colleagues, we could imbibe the learnings to explore our potentials. Mainly, Mr Venkateshwarlu as the father, Sridevi as Mother and Teja as Brother has always been the backbone of my foundation; they bolstered and propelled my limits in training abilities. I also want to thank our closest companion Ripughna Rishitosh who supported me intellectually at extreme occasions. Lastly, I would like to thank every one of my closest family and friends that motivated me to reach the heights of success. "

-Sri Ram Nidamanuri

"I, myself would like to give my heartfelt gratitude to my father Mr P.Sai Reddy and my mother Mrs P.Jayalaxmi and my little sisters Ms P.Sahithi Reddy and Ms.K.Devika Reddy and to my little brother Mr.K.Sowmith Kumar Reddy for being and supporting me with every step of my life. Me being here is all because of people that stood with me all my life, and I would thank all my friends and family members. On the last note, I would like to dedicate my work and the progress in my life to my parents Mr.& Mrs. Sai Reddy."

-Santosh Kumar Reddy Peddireddy

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Chapter 1

Introduction

1.1 Overview

Technology has expeditiously evolved which resulted in an increase in competition, this phenomena leads researches to find new possibilities of improvements within the areas of software development and its process [5]. Software development process is the process of dividing software development work into distinct phases. This makes it easier to manage the project and improve the efficiency of the work. The implementation of software development process in building software applications is called software development life cycle(SDLC) [6].

Requirement gathering is the phase where developers gather business and technical requirements of the project. From the collected requirements design and build of the software is determined in the design phase [7]. Solution for the problem is designed and implemented through code in development phase. Testing phase is where testers execute various tests to ensure that everything works as planned. In deployment phase the solution is delivered to the user. Finally, in the maintenance phase issues are addressed if needed or found.

Requirements gathering is the first phase of the software development life cycle. Requirements are the basis for every project, defining what the stakeholders like customers, suppliers, developers and businesses needs from a potential new system and also what the system must do in order to satisfy that need [8]. Requirements Engineering is a combination of four main activities that are:

- Requirements elicitation
- Requirements specification
- Requirements verification and validation
- Requirements management

The activity of gaining knowledge related to what are the user needs is requirements elicitation. To gather the requirements based on project needs, interaction is done with selected stakeholders in elicitation phase [9]. Requirements validation mainly focuses on producing a set of system requirements that are complete, consistent, important and reflect what the user needs [10]. To get a product that satisfies

the customer needs we need to take more care in the requirements phase and ensure that it is carried out correctly. This reduces the chances of repeating the requirement gathering phase again [11].Requirements verification is to check whether software meets specifications by analysing the requirements through methods like inspection, walk through, reviews [12]. Requirements management is the process of analyzing, documenting, tracking, prioritize the requirements and managing the communication with relevant stakeholders.

There are several kinds of research regarding requirements engineering. The topic we choose to do research is about factors affecting the selection of requirements validation techniques. Each organization has requirement validation techniques that are suitable for their way of working. We are trying to list out the validation techniques which are currently used by organizations, and we also intend to check what are all the factors that are related and that are influencing in selecting a requirement validation technique.

1.2 Aim and Objectives

1.2.1 Aim:

Analysing the factors in selecting a requirements validation technique and evaluating each factor's impact.

1.2.2 Objectives:

1. To get a list of validation techniques that are currently being used by organizations.

2. To analyse the factors that influence the selection of a requirement validation technique and rank the factors based on it.

1.3 Problem formulation

According to a survey, around 56% of the problems that arises during software development are the direct results of the errors from the requirement phase. To detect and rectify these errors, developers use requirement validation techniques. It plays an important role in ensuring that the product meets the customer's expectations [13]. There is less research done on the topic of selecting a requirements validation technique. By finding the most important factors that can influence the choice of the requirement validation method can save developer's time and effort and help the product reach user's expectations. This can help the developers by eliminating irrelevant methods from all requirement validation methods and recommending the best suited method for that scenario based on the factors. Our proposal is to find the most influential factors and selecting a suitable requirement validation technique based on it for the requirements validation phase.

Chapter 2

Background and Related Work

2.1 Requirements Engineering

Requirement: A requirement in terms of software refers to knowing what a system is a need-based on present and upcoming expected conditions and desires of stakeholders that relates to the market. It must say what system features will serve and satisfy this context. It explains how the system needs to be constructed [14].

Software product success depends on reaching the expectations of customers. Software requirements need the details of people from various fields like customers, and different type of stakeholders. They understand these requirements by modelling, analyzing, negotiating the stakeholder requirements. We need to focus on gathering requirements in required aspects of the software like usable, reliable, secure and economical. These requirements consist of the details of multiple factors [15].

Requirements engineering is beginning part of the software development process and all later phases are influenced by the requirements. Requirements engineering process discovers the objective of software development from obtaining the stakeholder needs and documenting these in a form that is suitable for analysis, communication and subsequent implementation. There will be challenges that occur in this process. Each stakeholder has different needs based on their views. Their goals may not be different and hard to structure; various factors do the satisfaction of these goals. Authors discussed the activities that constitute the field. Requirements engineering is a branch of software engineering that concentrates on real goals, functions, and constraints on software systems [16].

Requirements for a system is gathered, documented by requirements engineering. A requirement provides the details of how the system needs to develop and implement. These requirements are collected using various methods by consulting stakeholders. The RE process includes four main activities elicitation, specification/analysis, verification/Validation and Management as shown in figure 2.1. For the development of software, these requirements have documented. The documentation of these requirements is the baseline of later development phases of software development [17].

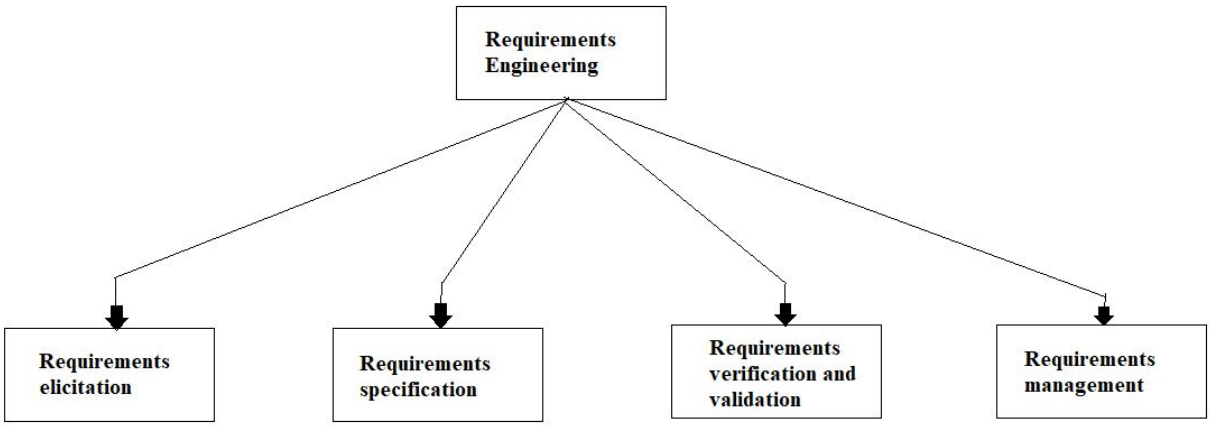

Figure 2.1: Requirement engineering activities

Requirements Elicitation: Requirements elicitation is the initial and vital stage of the requirements engineering process. Data is gathered in this phase to specify the requirements for software development. There are various researches done for requirements elicitation stating that this is the most important step that requires a lot of care to ensure that correct information is gathered [18]. The data is collected in the form of requirements. These requirements are gathered using various techniques like interviews, prototyping, using a questionnaire, brainstorming, role playing etc. This helps developer to understand the problem, widens the domain knowledge and acts as an input to the next stages.

Requirements Specification: Requirements gathering phase is crucial in the software development life cycle. Its time consuming to fix the mistakes that occur during this step. During requirement specification phase the requirements are identified, analysed and prioritized [19]. Software requirement models are produced that includes both functional and non functional requirements which are gathered during elicitation phase. The models used during this phase are ER diagrams, data flow diagrams (DFDs), data dictionaries, etc.

Requirements Verification and Validation: Requirements verification and requirements validation are two different methods used to ensure that the gathered requirements meet the user's needs. The distinction between those two terms is largely related to the specifications [20]. The difference between validation with respect to verification is:

- **Verification:** It is a process to check whether the software meets the specified requirements that are written during elicitation phase or not. This is a process of confirming that the designed and built product fully meets the documented requirements.

- **Validation:** It is a process to check whether the specifications written during the elicitation phase captures all the user's needs. During validation phase developers use different set of tasks that ensures that the software built is traceable to user's requirements.

In conclusion, requirements validation ensures that the documented requirements gathered during elicitation phase correctly captures the customer's needs and requirements verification ensures that the developed software meets those specifications or requirements. The combination of these two is called V&V generally means Validation and Verification which is used to check everything from documented user's requirements to developed software.

Requirements management: This is a continuous process that happen throughout the project. During this process the developers tries analyzing, documenting, prioritizing, tracking, and agreeing on the requirements gathered from user. This phase takes care of changing nature of requirements which means this step helps to incorporate the changes in requirements specified by the user at the later stages.

2.2 Requirement Validation

The last phase of requirements engineering is requirements validation. Requirements validation is done to make sure that requirements are complete and consistent according to user requirements. The requirements validation process detects errors in the software requirements specification (SRS). Ambiguities and conflicts in requirements are resolved during requirements validation [21]. These phase includes few steps that checks the requirements, the steps are:

- Consistency checks
- Completeness checks
- Validity checks
- Realism checks
- Ambiguity checks
- Verifiability.

These checks are performed during requirements validation phase to ensure the following things:

- The requirements should be consistent with other requirements, which means no two requirements should conflict or oppose each other.
- The requirements should be practically achievable.
- The requirements should be complete in every sense.
- The requirements must contain all relevant information.
- The requirements must address the actual needs of the system
- The requirements must be understandable by the stakeholders

- Every requirement must be described in a way that precludes different interpretations.

The output that we get after the requirements validation phase is the list of problems and actions that are agreed on for the detected problems as shown in figure 2.2. The Gathered requirements are the specification gathered from the end user during elicitation phase. The organizational standards are the specified standards followed by the organization according to which the system is to be developed. The organizational knowledge is used to estimate the realism of the requirements of the system. The list of problems as the name suggests are the list of problems that are detected during the requirement validation process. The list of agreed actions states the corrective action that needs to be taken to solve those problems [22].

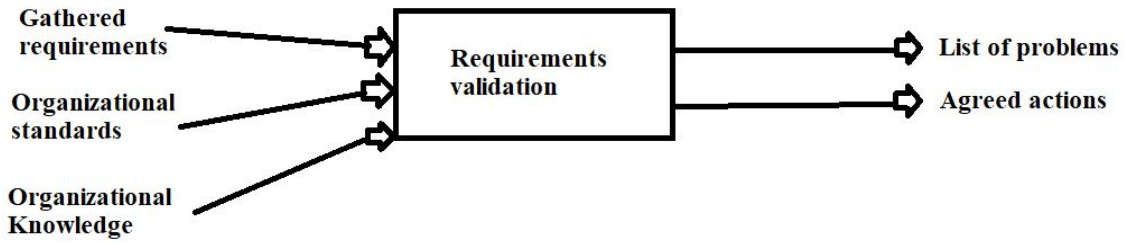

Figure 2.2: Requirement validation process

There are several techniques which are used individually or with other techniques to check the system [22], which are:

1. **Test case generation:**

   The requirements mentioned in the SRS document should be testable. If it is not testable then that generally means that the test is difficult or impossible to design. It is believed that if the test is difficult to design then it means that it will be difficult to practically implement the requirements to create the system and thus the requirements should be reconsidered.

2. **Prototyping:**

   In this validation technique, a basic working model (prototype) of the system is presented before the end-user, they test and experiment with the presented model to check if it meets the their specified requirements. This technique is generally used to take feedback from the user.

3. **Requirements reviews:**

   In this approach, a group of people from both organization side and user side carefully reviews the SRS. They review the document to check for any errors and ambiguity.

4. **Automated consistency analysis:**

   First, the requirement is structured in formal notation then a tool like CASE is used to check for any in-consistency or errors. For the identified inconsistencies and errors corrective actions are taken. In this approach, automated detection tool is used to search for type errors, missing cases, error in requirement specification, etc.

5. **Walk-through:**

   This is not an formally defined procedure. The approach follows few steps, that are:

   - Checking whether the idea is feasible or not
   - Obtaining the ideas and opinions of other
   - Checking the approval of others and reaching an agreement.

Many descriptions defined requirements validation and verification similarly. Maalem and Zarour [20] state that the requirements validation is a process to confirm that requirements are complete and have no conflicts within them. According to authors requirements needs to check of traceability, completeness, realism and verifiability. Requirement validation process ensures the requirements are necessary, enough for the excellent design phase that is good for the software [20].

Requirements validation occurs in various phases of requirements engineering like during requirements elicitation, requirements specification, requirements negotiation, requirements management.

Authors Julio Leite and Peter Freeman [23] have concentrated on requirements validation is the process of requirements elicitation. According to the authors, requirements validation is broad, and the early stages of validation have dealt with using informal checking, prototypes, formalism's, Domain-specific knowledge.

2.2.1 Requirements Validation and Verification:

Verification and validation purpose are to ensure that the product developed by reaching customer expectations and conditions [24]. Verification and validation enhance the development activity to reach in customer expectations [25]. In the case of requirements engineering the quality (in case of requirements the quality depends on correctness, consistency and completeness etc) in requirements is crucial in development activity due to the errors this phase makes more correction efforts and cost later [26]. Based on [27], verification and validation are consists of methods like reviews, static and dynamic analysis, testing and formal methods to make sure that the product is working on specified conditions imposed by client and developers [23].

Verification and validation words result in similarities in meaning and actions to prove each requirement is suitable for implementation by logical argument, inspection, modelling, simulation, analysis, expert review, test or demonstration. It concentrates on building the system right. These verification techniques verify every requirement. As follows, the verification of the requirements through the incorrect information received confirmation by laboratory tests or demonstration on a real system [28].

Requirements Validation

The intention behind requirements validation is to make sure that the collected requirements are suitable for the development of the system. Various methods and techniques carry out the validation process. The outcomes will be a list that has the problems list with the required documentation and the steps that need to take against those problems requirements validation results in the involvement of all stakeholders.

The validation process done to make sure of collected requirements is correct, complete, and consistent. Real-world solutions are generated and tested for establishing the requirements to be able to satisfy the system requirements and validation focus on Building the system right [28].

Validating requirements implies guaranteeing that (1) the set of requirements is right, finished, and steady, (2) a model that fulfils the requirements can be made, what's more, (3) a true arrangement can be assembled and tested to demonstrate that it fulfils the requirements. If the requirements determine a framework that decreases entropy without consumption of vitality, at that point the requirements are not suitable, and the task have delay.At examinations, the job of a tester needs to be requirements approval. Tester should pursue the vision and explicitly search for requirements approval and look after imperfections in the requirements.

Requirements Verification

Requirement verification is the activity of checking that the implementation, building of a component, and the system itself has been done correctly in accordance with the specified requirements. It consists of few confirmation checks performed throughout the product life cycle to ensure that the design, iterations, and the finished system fully meets the requirements. Those checks are:

- Inspection
- Analysis
- Demonstration
- Test
- Expert review

These checks could be something as straight forward as reading the specifications and comparing them against the system's code logic to make sure they both line up together. The verification process include the activities like walkthroughs, code reviews, testing like white box and black box testing. The whole process is to test the system to prove that it meets all the specified requirements at a particular stage of its development [28]. The checks can be further elaborated as:

1. **Inspection:**

   It is a thorough line by line checking of software logic with an intention of finding faults and confirming traceability of relevant requirements with the code.

2. **Expert review:**

   It is an assessment of the system by a board of experts. In this process the group of people monitors the working of the system, changes made during the development of the system in accordance with the requirements.

3. **Analysis:**

   This is about estimation of system resources and execution time. In this process predictions of system's or product's performance are made based on actual test results.

4. **Testing:**

   Testing involves separate equipment's or tools to run. This process also involves multiple or repetitive tests to collect the data of the product or the system that will prove or ensure that the requirements has been met..

5. **Demonstration:**

   Like the testing process, demonstration also involves multiple test but without any tools or equipment's. In this process developers use the system as it is to check whether the system does the same things as it is intended to do in accordance with the requirements specified by the user. It can be as simple as to press every button on the system or to use every controls to confirm that the system does what it is needed to do.

2.3 Requirement Validation Techniques

These techniques objective is to get completeness in gathered requirements [21]. Requirement validation techniques play a crucial role in detecting defects in the requirements. To complete the projects within time, cost, and according to user needs, these techniques will be helpful. Each requirement validation technique has its objectives and involvement of different stakeholders [20].

Requirements validation techniques used to maintain consistency, completeness and accuracy of elicited and specified requirements [21]. Each requirement validation technique has different functionalities. Each validation technique gives different types of validation in requirements. Different validation techniques provide different objectives. There are many types of requirements validation techniques in literature, and we list some of the techniques we found from literature and give a description of each validation technique [20].

Roles:(customers, users, Domain Experts, Software Engineers, Requirement Engineers, Project managers) Most of the works in requirements engineering, explains the exact role of the stakeholders in requirements validation. From the available literature, the participants are selected based on the involvement of validation in various phases. The responsibilities and participation of each role have described in multiple sections (Background, Literature results) [20].

2.4 Related Work

Raja et al. [21] discussed points about requirements validation techniques that are, validation techniques in academia, validation techniques pros and cons, Importance of selecting a validation technique. Based on the literature review, the above points described in a particular way. Authors made a chart list from collected data to compare all validation techniques related to various factors like Cost, Size, usability, customer involvement based on literature review. This research will help us get an overview of the firm and weak points of a validation technique in terms of our aspect methodology.

Zafar et al. [29]mentioned that the requirements engineering practices in developing countries are not up to full potential. They have performed a systematic literature review and also surveyed to find the factors for these situations. The conclusion depicted by a survey mentioning issues like lack of time, lack of budget, lack of dedicated team and communication difficulties.

Hashim et al. conducted a study. [30] to compare the IT project performance and factors that are influencing the success of the project. A literature review and an online survey were performed. Through the literature review, the factors that are affecting the success of a project found they possess unclear requirements, overdrawn budget and, problems in schedule management, and change management. Out of these, the scope of change management is the most critical factor for the success of projects.

Motekar et al. proposed a requirement engineering tool. [31], which is auto-mated, which supports requirement engineers to effectively communicate with client stakeholders to validate requirements virtually in real-time. The tool is augmented with real-time communication and collaboration support to allow multiple stakeholders. This research concentrates more on stakeholder factors in requirements. Their results effect in improving communication with stakeholders. They acknowledged only one factor in this study.

Yousuf et al. [32] discussed global software development factor influence in requirements validation. The research wants to elaborate on the negatives in some of the existing requirements validation techniques that allow Global software development factors recently. For this research, they gathered factors in Global software engineering and existing requirements validation techniques efficiency in those factors. By measuring the usage of each factor, they measured the usage of each factor they measured the critical of each requirement validation technique in Global software development.

Fenkam et al. proposes a new model of reviewing and testing requirements by interpreting them into a graphical model by using CORBA. [33] in this study. CORBA used to accomplish communication between the user interface and the specification. The main objective of the research is by doing a case study, providing visual requirements validation and application of requirements validation for a reusable component. The research focuses on the interpretation of requirements to increase validation standards, whereas our research focuses on the crucial factor that influences in selecting a requirements validation technique.

Lee et al. [34] proposed a customer requirements validation based on their behaviour models. They stated that the success of the project mostly depends on customer requirements. The objective of the research is to create a framework to evaluate the requirements based on customer behaviours. They designed customer mental understanding based on their motivations, thought processes and emotional backgrounds. The research mainly focuses on improving the validation process by understanding customer behaviour in requirements.

The author's Winter et al. [35] proposed a virtual environment modelling for requirements validation of high consequence systems. Based on systems complexity, the model allows the specifier to understand the requirements. The model takes the information of Domain expert, physical model, Symbolic model to create a visual model. The research objective is to provide the correctness of formalization satisfactory, which is a significant issue in high consequence systems. Although the application of this model is costly, it is so much useful for the development of high consequence systems.

Chapter 3

Method

3.1 Research Questions

1. What requirements validation techniques are currently being practiced in software organizations?
2. What are the factors that are influencing the selection of requirements validation techniques?
3. What are the factors that has the more influence in selecting a requirement validation technique?

3.2 Research Methodology

In this study, we focus on finding the critical factors that affect the selection process of requirements validation techniques. The data we obtained is qualitative. To get in-depth knowledge about requirements validation techniques and factors, we did a literature review. Based on the literature review, the research and survey questions created. Using the surveys, we collected the opinions, views related to factors influencing the selection of requirements validation techniques.

3.2.1 Literature Review

A literature review helps in gaining knowledge about any subject by studying existing research articles [36]. Based on the research questions, our research needs the information of requirements validation techniques and factors influencing them. To gain knowledge about those topics, we have studied the existing literature works to get the list of requirements validation techniques from the current research articles. In the case of factors, there are few types of research works available, so we choose the snowballing method to extract the data from existing literature based on Wohlin guidelines [37]. Snowball sampling helps in finding a more significant number of research papers related to our research area.

Snowball Sampling

The Snowball sampling process considered as a literature study as the procedure of snowball is an independent search approach [37]. The reason for selecting a snowball process in the literature to extract as many articles that are relevant to the research

studies. In our research, we need to identify the factors which influence the requirements validation techniques practised in organizations. For this study, we need to form an appropriate start set article for the snowballing procedure to find relevant papers from the database [37]. The first step to start a snowball procedure is to find a competent and suitable article related to the study and therefore, to do an in-depth data collection of articles from this procedure.

Study Identification

Study identification is the process of searching for articles to obtain necessary data regarding research questions.

- **Start Set Identification:**We have followed these steps for identifying the start set for our research. The information of our procedure is presented below.
  - The keywords are selected based on the research question and suitable to our aims.
  - Keywords are elaborated by adding suitable words to it for getting better results.
  - From the keywords we have formed search strings and used in the databases for obtaining better results.
  - Above steps are repeated multiple times to get similar articles from the search string.
  - We have finalized the keywords, and the search string, that relates to our research which is relates to our research, was observed to obtain better results.
- **Keywords**
  - **Step 1:** Requirements engineering, Requirements validation, and Requirements validation techniques.
  - **Step 2:** Phases in Requirements engineering, Requirements validation process, and Factors influencing requirements validation techniques. These keywords are selected to form the search string. The search string sets we have got is to get articles which are relevant to our study.
  - **Search String Set 1:** (Requirements engineering, Requirements validation, and Requirements validation techniques).
  - **Search String Set 2:** (Phases in Requirements engineering, Requirements validation process, and Factors influencing requirements validation techniques).
- **Database:** The databases we have chosen to find the articles are GOOGLE SCHOLAR, IEEE EXPLORE. Based on these search strings we gone through databases to find out the articles which are suitable for our study. We have got more articles from GOOGLE SCHOLAR.

- **Preliminary Start Set of articles:** From the search string set 1 and search string 2, we found the articles that are related to our research and ignore the articles which are not associated with our research by checking titles and reading through abstracts. The start set details of our research has mentioned at literature review results.

Inclusion and Exclusion Criteria

- **Inclusion Criteria:**
  - The articles which are related to the requirement validation techniques considered for our research.
  - Articles written in English language is preferred for the research.
  - Articles which are related to scholar articles, Journals, empirical studies are preferred.
  - Articles which have full text access is considered.
- **Exclusion Criteria:**
  - Articles which are not related to requirement validation techniques are excluded.
  - Repeated and duplicate articles are excluded.
  - Articles which are not in English language are excluded.
  - Articles which are not related to articles, journals (ex; books) are excluded.

Snowballing consists of two different processes of collecting relevant articles. They are the Backward snowballing and the forward snowballing procedure. A detailed explanation of the snowballing procedures are as follows:

- **Forward Snowballing Procedure:**
  The forward snowballing procedure implemented by considering the citations of every article selected from the start set of articles [37]. The article citation checked in different online scholarly database platforms such as google scholar for every study. The research study should satisfy the following set of rules to continue the process of forwarding snowballing iterations. The selection criteria is as follows:
  1. Examining the title of the referred article.
  2. Examining the abstract of the referred article.
  3. If the abstract is unclear, entire article is studied to understand it.
- **Backward Snowballing Procedure:**
  The backward snowballing procedure implemented by considering the references of every research article presented in our study. The articles searched in the online database such as Google scholar for every study. The research study should satisfy the following set of rules to continue the process of backward snowballing iterations. The selection criteria is as follows:

1. Examining the title of the referred article.
2. Examining the abstract of the referred article.
3. If the abstract is unclear, entire article is studied to understand it.

3.2.2 Survey

The survey was done to get feedback about the topic to answer the research questions. A survey is useful in collecting opinions and views from various kind of people who are related to our research requirement [38]. Using a web-based survey, we can gather information from experienced people and data collection from various people is easy. So, we have selected survey as our research methodology. Generalized conclusions obtained by using the survey's [37].

In this study, we focus on finding the critical factors that affects the selection process of requirements validation techniques. The data we obtained is qualitative. To get in-depth knowledge about requirements validation techniques and factors, we did a literature review. Based on the literature review, we performed the research and created survey questions. Using the surveys, we collected the opinions, views related to factors influencing the selection of requirements validation techniques.

An open questionnaire was created based on our research questions. In order to get requirement validation techniques used in organizations, we list out the requirement validation techniques that are found in the articles using literature review and ask them to choose the requirement validation technique which they are using in their organizations. In case if they have any different requirement validation technique, we created a question for asking any other requirement validation technique that is apart from our list of requirement validation techniques. We list out the factors that are found in the literature review and ask them to state the factors they consider in the selection of requirement validation techniques. From the selected list of factors, we ask them to rate the factors in order to get each factor influences in choosing a requirement validation technique.

Alternative methods:

Case study and experiment are the alternative research methodologies for the research. A case study in software engineering aimed at broad contexts of the research area. The data collection methodologies in case studies lead to gather less information about our research within the meantime. It may produce similar kind of results like a survey, but due to data collection and analysis not suitable for our research case study is not taken. Interviews allow us to have face to face conversations, and due to counters and encounters on the topic. It takes time for selecting participants from the survey and contacts them. Due to time concern, we neglected interviews and created more open-ended questions in the survey. To experiment, we need to test the hypothesis for factors with requirement validation techniques. Since it is dicult to experiment on extensive data, we have not selected experiment as our research methodology for our research.

Survey Planning

Objective: A survey conducted to obtain knowledge regarding a particular study and to achieve the objectives. This study should be analyzed and formulated into research questions in order to make the information required for the study. By this action, we get the representation of the scope of the research and helps us to identify the initial participants in the survey, which provides us with quality information. The objectives of our research are :

- To list out the techniques that currently being used in the organizations
- To identify the factors that are considered while working with a validation technique
- To identify the most influential factor of all the factors.

Scheduling the survey:

The survey conducts for a total of twelve weeks, i.e., from January 2020 to March 2020. The survey questionnaire formed from the results of the literature review.

Planning and collecting resources for the survey:

A survey is conducted through an online platform (LinkedIn) where the survey link is sent to the contacts. The people that are involved in the survey are mostly working with the requirement engineering practices. An invitation sent to the practitioners where a brief introduction about our research will be provided. After accepting our invitation, a link that directs to a survey questionnaire for practitioners to gain their quality information for our study. A reminder mail sent to practitioners at the end of every weekend who have not addressed the survey.

Survey Design and Execution

Survey Questionnaire planning:

The survey questionnaire is used for the data collection in our research study. The survey is designed to cover all the objectives and help us with our study. The survey questionnaire consists of a total of nine questions, out of which few are close-ended questions, and some are open-ended questions. The questions are formulated with ease to understand and to state the objective of the problem clearly. In a total of nine questions, four questions are about the demographics of the participants, i.e., their role in the organization, the experience they have, their work in the requirements engineering phase.

The remaining questions are regarding the requirements validation techniques and the factors. After the demographic questions, participants were asked about the validation techniques that are used in their organization: The factors that they

considered while working on validation techniques. In the end, they were asked about their opinions regarding choosing factors with a clear description.

Validating the questionnaire:

The survey questionnaire is validated by using the guidelines proposed by Kitchenham et al [39]. In [39], a set of guidelines and principles were recommended to validate the questionnaire. A mock survey was conducted to check the understandability of the questionnaire as different people have a different expression of words. After the mock survey is performed, the provided feedback is used to rephrase the questions for a clear understanding of everyone involved in the survey.

The corrected questionnaire is the final questionnaire which has a total of nine questions is sent out to the participants as a survey through an online platform. The following is a link to the survey used in this thesis: https://forms.gle/uhnEGVxJVTj3YwvHA.

Participants selection for the survey:
Kitchenham et. al [39], has stated sampling methods for conducting a survey. The sampling method is used to interfere with the target population. The sampling method consists of two types, which are probabilistic sampling methods and non-probabilistic sampling methods. Probabilistic sampling is where the target audience has a non-zero probability of including in the sample, and the Non-probabilistic sampling is about choosing the target population that is available as per their convenience. Non-probabilistic sampling is used for the participants in the study. Non-probabilistic sampling consists of convenience sampling, snowball sampling, quota sampling, and focus groups.

The sampling we have used in our study is convenience sampling as it involves obtaining responses from accepting our invitation to take part in our survey. The target population for our research is Requirements Analyst, Business Analyst, Product Owners, Scrum Master, Project Manager and, Tester. The survey is conducted only in the Sweden region, and the target population are the working people from Sweden.

Requirement analysts and project managers select validation techniques based on their previous experience and project criteria [40], and they have many roles in the requirements phase. So, requirement analyst and project managers from each organization are chosen as the sample size of our population. The participants involved in this phase should have experience mainly within the requirements domain who have a prominent role in selecting requirements validation. Participants are chosen from online platforms like LinkedIn to get contact. The keywords used are related to requirements fields such as requirements analysts, requirements managers.

3.2.3 Narrative Analysis

Narrative analysis is one of the data analyzing methods that analyze the qualitative and quantitative data from the literature. Narration is a way of expressing one's

view through story-telling. Narrative analysis aims to identify the kind of stories told about the researched phenomenon. In this research we opted survey to collect the required data in the form of natural language (NL) as written sentences. The natural language processing, to extract the useful information from the sentences and get best possible interpretation out of it requires narrative analysis [32]. This is an approach that allows authors to construct and implement views and stories expressed by narrators [29]. It generates and represents the data in narrative form and includes the narrative data to the synthesis process [41]. In the narrative analysis, data collected from the survey summarized as a theory or an oral story, where responses are analyzed irrespective of their (responses) irregularities. Moreover, narrative analysis helps in prioritize or organize the data in a well-structured manner and gives a proper understanding of the collected data [42].

Chapter 4

Results and Analysis

4.1 Results of Snowball Sampling

Start Set for snowball sampling:

The database we chose for selecting the research papers is Google scholar. A specific search string is used for selecting the papers, and we have chosen 253 papers that are related to our study. In these 253 papers, we have chosen 27 papers that are relevant to the study. Out of these 27 papers, we have removed 25 papers after thoroughly checking the abstracts and the full text of the paper and the two papers we chose exactly match our field of study. The start set articles for the research are as follows:

Paper ID	Start Set of the Snowball Sampling
P1	Maalem, Sourour, and Nacereddine Zarour. "Challenge of validation in requirements engineering." Journal of Innovation in Digital Ecosystems 3.1 (2016): 15-21.
P2	Raja, Uzair Akbar. "Empirical studies of requirements validation techniques." 2009 2nd International Conference on Computer, Control and Communication. IEEE, 2009.

Table 4.1: Start Set of Snowball Sampling

4.1.1 Iteration 1 of Snowball Sampling

First Iteration of Forward Snowballing:

In the first iteration, forward snowballing is a total of 54 papers have identified and reviewed by abstract and full text to check for the relevance of the paper to the study. Out of the 54 papers, we have followed and applied the inclusion and exclusion criteria and selected 15 papers that are in the English language and with no repetition. The results of the first iteration of forward snowballing are as follows:

Paper ID	Results from the First Iteration of Forward Snowballing
P3	Mani, P., and M. Prasanna. "Validation of automated test cases with specification path." Journal of Statistics and Management Systems 20.4 (2017): 535-542.

P4	Zainuddin, Fauziah Binti, et al. "Reviewing the Challenge and Practices of Human Factor Involvement in Requirement Specification Validation." Advanced Science Letters 24.10 (2018): 7322-7327.
P5	RMOSA, ABDELRASOUL YAHYA IBRAHIM. An Automated Technique to Support Generation and Validation of Software Specifications. Diss. Sudan University of Science & Technology, 2018.
P6	Maalem, Sourour, and Nacereddine Zarour. "A cognitive approach of collaborative requirements validation based on action theory." International Journal of Information and Communication Technology 14.3 (2019): 336-355.
P7	Okesola, Julius Olatunji, et al. "Reviewing the Role of Stakeholders in Requirement Engineering: A Stakeholder's Theory Perspective." Asian Journal of Scientific Research.
P8	Iqbal, Danish, et al. "Requirement Validation for Embedded Systems in Automotive Industry Through Modeling." IEEE Access 8 (2020): 8697-8719.
P9	Khan, H., et al. "An empirical study of software requirements verification and validation techniques along their mitigation strategies." Asian Journal of Computer and Information Systems 3.03 (2015).
P10	ROBINSON, Mark. "Automatic acceptance test case generation from essential use cases." New Trends in Software Methodologies, Tools and Techniques: Proceedings of the Thirteenth SoMeT_14 265 (2014): 246.
P11	Moketar, Nor Aiza, et al. "TestMEReq: generating abstract tests for requirements validation." 2016 IEEE/ACM 3rd International Workshop on Software Engineering Research and Industrial Practice (SER&IP).IEEE, 2016.
P12	Mokhtar, Siti O., et al. "Issues and challenges of requirements review in the industry." Indian Journal of Science and Technology 10.3 (2017): 1-5.
P13	Condori-Fernández, Nelly, et al. "Analyzing the effect of the collaborative interactions on performance of requirements validation." International Working Conference on Requirements Engineering: Foundation for Software Quality. Springer, Cham, 2014.
P14	dos Santos, Jemison, et al. "Software requirements testing approaches: a systematic literature review." Requirements Engineering: 1-21.
P15	Dahr, Jasim Mohammed. An investigation of requirements traceability practices in software companies in Malaysia. Diss. Universiti Utara Malaysia, 2016.
P16	Prokop, James A. Effective electronic security: process for the development and validation from requirements to testing. NAVAL POSTGRADUATE SCHOOL MONTEREY CA DEPT OF NATIONAL SECURITY AFFAIRS, 2013.
P17	Jassim, Thamir Naeem. "Requirements validation techniques: A case of prototype of the Technical Institute for Administration." Journal of AL-Qadisiyah for computer science and mathematics 6.1 (2014): 1-10.

Table 4.2: First Iteration Of Forward Snowballing.

First Iteration of Backward Snowballing:

Our first iteration with the backward snowballing, we have referred with a total of 53 papers. Out of these 53 papers, we have selected eight papers that are relevant to our study and also by following the inclusion and exclusion criteria for selecting the papers. The removal of 45 papers is done based on; the name of the file, by reading the abstract and finally reading the full text of the paper. The results of the first iteration of backward snowballing are as follows:

Paper ID	Results from the First Iteration of Backward Snowballing
P18	Sommerville, Ian, and Pete Sawyer. Requirements engineering: a good practice guide. John Wiley & Sons, Inc., 1997.
P19	Leite, Julio Cesar Sampaio do Prado, and Peter A. Freeman. "Requirements validation through viewpoint resolution." IEEE transactions on Software Engineering 12 (1991): 1253-1269.
P20	Groshek, Tony, and Nina Dzamashvili-Fogelström. "Test-case Driven Inspection of Pre-project Requirements.
P21	Dzamashvili-Fogelström, Nina, and Tony Gorschek. "Test-case driven versus checklist-based inspections of software requirements–an experimental evaluation." 10th Workshop on Requirements Engineering (WER 07). 2007.
P22	Mogyorodi, Gary E. "What is requirements-based testing." Crosstalk: The Journal of Defense Software Engineering 16.3 (2003): 12.
P23	Laitenberger, Oliver. "A survey of software inspection technologies." Handbook of Software Engineering and Knowledge Engineering: Volume II: Emerging Technologies. 2002. 517-555.
P24	Siddiqi, Jawed, et al. "Towards a system for the construction, clarification, discovery and formalisation of requirements." Proceedings of IEEE International Conference on Requirements Engineering. IEEE, 1994.
P25	Fagan, Michael. "Design and code inspections to reduce errors in program development." Software pioneers. Springer, Berlin, Heidelberg, 2002. 575-607.

Table 4.3: First Iteration Of Backward Snowballing.

4.1.2 Iteration 2 of Snowball Sampling

Second Iteration of Forward Snowballing:

The second iteration of forward snowballing, we have a total of 50 papers that are related to the field, and we have selected 21 papers out of the total that is relevant to our study by following the requirements of inclusion and exclusion criteria. The remaining papers were rejected after reviewing the name, abstract and full text of the file. The results of the second iteration of the forward snowballing are as follows:

Paper ID	Results from the Second Iteration of Forward Snowballing
P26	Padmanabhan, Mani. "A Study on Transaction Specification based Software Testing for Internet of Things." 2018 International Conference on Current Trends towards Converging Technologies (ICCTCT). IEEE, 2018.

P27	Zainuddin, Fauziah binti, Ruzaini bin Abdullah Arshah, and Rozlina binti Mohamad. "Software visual specification for requirement engineering education." Proceedings of the 10th International Conference on E-Education, E-Business, E-Management and E-Learning. 2019.
P28	Jarzębowicz, Aleksander, and Piotr Marciniak. "A survey on identifying and addressing business analysis problems." Foundations of Computing and Decision Sciences 42.4 (2017): 315-337.
P29	Raza, Muhammad Mohsin, et al. "Impact of Stress on Software Engineers Knowledge Sharing and Creativity [A Pakistani Perspective].
P30	Bedoya, Albeiro Espinosa, Yury Montoya Perez, and Hector Alejandro Puerta Marin. "A review on verification and validation for embedded software." IEEE Latin America Transactions 14.5 (2016): 2339-2347.
P31	Jarzębowicz, Aleksander, and Katarzyna Połocka. "Selecting requirements documentation techniques for software projects: a survey study." 2017 Federated Conference on Computer Science and Information Systems (FedCSIS). IEEE, 2017.
P32	Moketar, Nor Aiza, et al. "A Template-Based Test-Authoring Tool to Write Quality Tests for Requirements Validation." Asia Pacific Requirements Engineering Conference. Springer, Singapore, 2016.
P33	Moketar, Nor Aiza, et al. "An automated collaborative requirements engineering tool for better validation of requirements." Proceedings of the 31st IEEE/ACM International Conference on Automated Software Engineering. 2016.
P34	Moketar, Nor Aiza, et al. "TestMEReq: generating abstract tests for requirements validation." 2016 IEEE/ACM 3rd International Workshop on Software Engineering Research and Industrial Practice (SER&IP). IEEE, 2016.
P35	Couto, Rui, António Nestor Ribeiro, and José Creissac Campos. "Validating an approach to formalize use cases with ontologies." arXiv preprint arXiv:1603.08632 (2016).
P36	Moketar, Nor Aiza, et al. "TestMEReq: Automated Acceptance Testing Tool For Requirements Validation." International Symposium on Research in Innovation and Sustainability. Vol. 2014. 2014.
P37	Moketar, N. A., and M. Kamalrudin. "Extraction of Essential Requirements from Natural Language Requirements." Journal of Telecommunication, Electronic and Computer Engineering (JTEC) 10.2-2 (2018): 35-38.
P38	Maciel, Daniel Ademar Magalhães. "Model Based Testing-From requirements to tests." (2019).
P39	Paiva, Ana CR, Daniel Maciel, and Alberto Rodrigues da Silva. "From Requirements to Automated Acceptance Tests with the RSL Language." International Conference on Evaluation of Novel Approaches to Software Engineering. Springer, Cham, 2019.
P40	Anjum, Rubia, et al. "A Meta-Model to Automatically Generate Evolutionary Prototypes from Software Requirements." Proceedings of the 2019 7th International Conference on Computer and Communications Management. 2019.

P41	Maciel, Daniel, Ana CR Paiva, and Alberto Rodrigues da Silva. "From Requirements to Automated Acceptance Tests of Interactive Apps: An Integrated Model-based Testing Approach." Proceedings of the 14th International Conference on Evaluation of Novel Approaches to Software Engineering. SCITEPRESS-Science and Technology Publications, Lda, 2019.
P42	Nordin, Azlin, Nurul Husna Ahmad Zaidi, and Noor Asheera Mazlan. "Measuring software requirements specification quality." Journal of Telecommunication, Electronic and Computer Engineering (JTEC) 9.3-5 (2017): 123-128.
P43	Babu, R. Bulli, Mr S. Jalaiah, and Mr P. Naga Bhushanam. "Quality improvement measures for Software Requirement Specification."
P44	White, Timothy E., Ronald Iammartino, and John M. Fossaceca. "Assessing the impact of requirements review on quality outcomes." Quality and Reliability Engineering International 34.5 (2018): 882-893.
P45	Nordin, Azlin, Nadzurah Zainal Abidin, and Sara Hanum Mohd Zaini. "Collaborative requirements review." International Journal of Engineering & Technology 7.2.14 (2018): 66-69.
P46	Ryynänen, Tapani, Heidi Korhonen, and Iris Karvonen. "Customer needs driven engineering platform development." ISPIM Conference Proceedings. The International Society for Professional Innovation Management (ISPIM), 2017.

Table 4.4: Second Iteration Of Forward Snowballing.

Second Iteration of Backward Snowballing:

The second iteration of backward snowballing, we are referred with 105 papers, and out of these, we have selected eight papers by following the inclusion and exclusion criteria. The remaining 97 papers were excluded after reviewing the name of the file, reading the abstract and full text of the file. The results of the second iteration of the backward snowballing are as follows:

Paper ID	Results from the Second Iteration of Backward Snowballing
P47	Ohlsson, Stellan, and Pat Langley. PRISM tutorial and manual. University of Calif., 1986.
P48	do Prado Leite, Julio Cesar Sampaio. Viewpoint Resolution in Requirements Elicitation. University of California, Irvine, 1968.
P49	SIGSOFT, ACM. "Special Issue on Rapid Prototyping." ACM SIGSOFT Software Engineering Notes 7.5 (1982).
P50	Morrey, Ian, et al. "Use of a specification construction and animation tool to teach formal methods." Proceedings of 1993 IEEE 17th International Computer Software and Applications Conference COMPSAC'93. IEEE, 1993.
P51	Russell, Glen W. "Experience with inspection in ultralarge-scale development." IEEE software 8.1 (1991): 25-31.

P52	Shull, Forrest, Ioana Rus, and Victor Basili. "Improving software inspections by using reading techniques." Proceedings of the 23rd International Conference on Software Engineering. 2001.
P53	Votta Jr, Lawrence G. "Does every inspection need a meeting?." Proceedings of the 1st ACM SIGSOFT symposium on Foundations of software engineering. 1993.
P54	Shull, Forrest, Ioana Rus, and Victor Basili. "How perspective-based reading can improve requirements inspections." Computer 33.7 (2000): 73-79.

Table 4.5: Second Iteration Of Backward Snowballing.

4.1.3 Iteration 3 of Snowball Sampling

Third Iteration of Forward Snowballing:

The third iteration of forward snowballing, we have a total of 40 papers that are related to the field, and we have selected six papers out of the total that is relevant to our study by following the requirements of inclusion and exclusion criteria. The remaining papers were rejected after reviewing the name, abstract and full text of the file. The results of the second iteration of the forward snowballing are as follows:

Paper ID	Results from the Third Iteration of Forward Snowballing
P55	Jarzębowicz, Aleksander, and Kacper Sztramski. "Identification, Assessment and Automated Classification of Requirements Engineering Techniques." Computer Science On-line Conference. Springer, Cham, 2019.
P56	Kosiuczenko, Piotr, and Zbigniew Zieliński, eds. Engineering Software Systems: Research and Praxis. Springer International Publishing, 2019.
P57	Yang, Yilong, et al. "Automated Prototype Generation from Formal Requirements Model." IEEE Transactions on Reliability (2019).
P58	ang, Yilong, Wei Ke, and Xiaoshan Li. "RM2PT: Requirements Validation through Automatic Prototyping." 2019 IEEE 27th International Requirements Engineering Conference (RE). IEEE, 2019.
P59	Ferreira, Sérgio Miguel Almeida. "Mutation-based Web Test Case Generation." (2019).
P60	Mostafa, Salama A., Saraswathy Shamini Gunasekaran, and Shihab Hamad Khaleefah. "Integrating Fuzzy Logic Technique in Case-Based Reasoning for Improving the Inspection Quality of Software Requirements Specifications." International Conference on Applied Computing to Support Industry: Innovation and Technology. Springer, Cham, 2019.

Table 4.6: Third Iteration Of Forward Snowballing.

Third Iteration of Backward Snowballing:

The third iteration of backward snowballing, we are referred with eight papers, and out of these, there were no papers that are matching with our preferences. We have not found any articles that support our research study. We have done the inclusion and exclusion criteria

for any chance in finding an article. Furthermore, we have not found any article, so the snowballing procedure has been terminated.

4.1.4 Iteration 4 of Snowball Sampling

Fourth Iteration of Forward Snowballing

The fourth iteration of forward snowballing, we are referred with six papers, and out of these, there were no papers that are matching with our preferences. We have not found any articles that support our research study. We have done the inclusion and exclusion criteria for any chance in finding an article. Furthermore, we have not found any article, so the snowballing procedure has been terminated.

Fourth Iteration of Backward Snowballing

The fourth iteration of backward snowballing, the process is terminated at the third iteration of the snowballing procedure. The process ends here.

4.2 Results of Literature Review

4.2.1 Requirement Validation Techniques

Requirements Inspections [43] [44] [45]

In the software development process, a large number of requirements gathered from various stakeholders. The people mainly involved in gathering requirements are project managers, analysts, customers, etc., so these gathered requirements are used to create a software requirement specification(SRS) document. The SRS document is done by requirements author and later used in phases like design, coding, and testing. While working with these requirements there often occurs a few inconsistencies, ambiguity, and redundancies.

When a large number of requirements gathered, a few risks might occur in later phases of design. To maintain a high-quality standard of the requirements, we need colossal effort is essential for a document.

If gathered requirements are in large numbers, few risks might occur in later phases of development such as the design process. A lot of work has to be put into the document to maintain the quality standards of the requirements.

The requirement review is the starting step of a validation process. The review has done to preserve the quality of requirements and to ensure they have the correctness, Completeness, verifiability, feasibility, clarity. The requirement review in software companies is done by the use of peer-review, where skilled inspectors read through each requirement for the potential faults, and they handed back to requirements author. The requirements author manually read through the submitted review and identifies and modify useful reviews and remove the non-useful reviews and also the author goes through the original SRS to search for faults that have occurred because of modified reviews. The whole process requires a lot of human resources, and it is a long, tedious and hectic process.

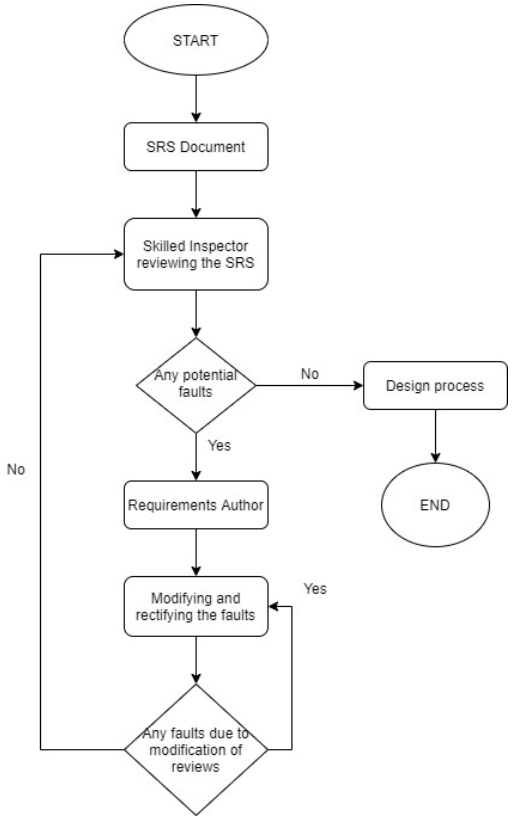

Figure 4.1: Inspection process [1]

After several reviewers from various knowledge areas had worked on the SRS, a formal review checklist formed to showcase all the requirements which are faulty with a particular nature such as incompleteness, ambiguity, redundancy, etc. The review is done to clear the faults of the requirement by each of its nature. The requirement review works to maintain the requirements with correctness, Completeness, verifiability, feasibility, clarity.

Prototyping [46] [21]

Prototyping primarily used for the analysis and the application of user requirements, but it can also be used to check the feasibility, consistency, and completeness of system design. Prototyping helps the developers to get a better understanding of the positive and negative parts of the requirements, and it also benefits developers to understand the customer's perspective. A considerable number of issues that have surfaced throughout this process in understanding the customer's requirements were cleared by the developers using prototyping. The prototyping operates as a communication medium between the developers and the customers, which helps them to learn about each other's perspectives without any in-depth understanding of each other's field. Experienced use of prototype will unveil the requirements which are unknown or did not think off, and this requires an experienced developer. The prototype evaluation is done continuously until all the objectives of the system are achieved. The prototyping work in done in two ways:

- **Throw Away Prototyping:**
  The practice of building a quick, cheap, and an early version of a system which

does not possess all the features of the final version is known as Rapid or Throw-away prototyping. It helps in identifying the poorly understood requirements, and it helps to resolve the inconsistencies between the developers and customers. When both developers and customers consent to a set of requirements, the prototype gets disposed. Then the software requirement specification(SRS) is modified by including the concurred requirements. This process is iterative up until all the requirements are identified, and the prototype is flawless.

- **Evolutionary Prototyping:**
  The practice of developing a final prototype by continuous improvement of requirements is known as Evolutionary prototyping. The confirmed set of requirements only develops the evolutionary prototype. A functional prototype was built, and it is iteratively modified based on provided feedback.

Viewpoint Oriented Requirement Validation [23] [2] [21]

Viewpoint resolution is a validation method in the early stages of the requirement elicitation phase. Viewpoint resolution is about the disparities between two different viewpoints and, the analysis and evaluation of these disparities and also to integrate these different solutions to form a single representation. Two functions occur in viewpoint resolution. Those functions are Viewpoint analysis and Viewpoint reconciliation. The viewpoint analysis deals with the fact validation of requirements and reconciliation works in the communication part of the requirement engineering process. The viewpoint resolution is focused on the problems in identifying the differences and evaluating these differences. A few terms are discussed below, which were used to understand the working of the viewpoint resolution.

- **The Universe of Discourse:** It is an overall context where the software is developed. It stores all the sources of information and the people involved in software development.

- **Actors:** The people involved in the Universe of discourse are referred to as actors. The actors are of two types: customers on the demand side, and software engineers from the supply side.
  The customers are mostly composed of buyers, operators, information suppliers, information customers, and the supply side is composed of different levels of management, consultants, different skill levels of analysts.

- **Viewpoint:** Viewpoint is defined as the standing or mental position of an actor when examining or observing the Universe of discourse. The viewpoint is identified by the actor and his role in the Universe of discourse.

- **Perspective:** Perspective is a set of facts that are observed and modelled according to a particular modelling aspect and viewpoint.

- **Views:** The view is formed by the integration of perspectives and is achieved by the view-construction process.

- **Hierarchies:** Hierarchies used in the Universe of discourse are of two types: is-a hierarchy of concepts and a parts-of hierarchy of concepts.

- **VWPL:** VWPL is a special language which is derived from PRISM [47], and it is used to represent viewpoints.
  VWPL is used by two or more analysts who are required to perform the method of

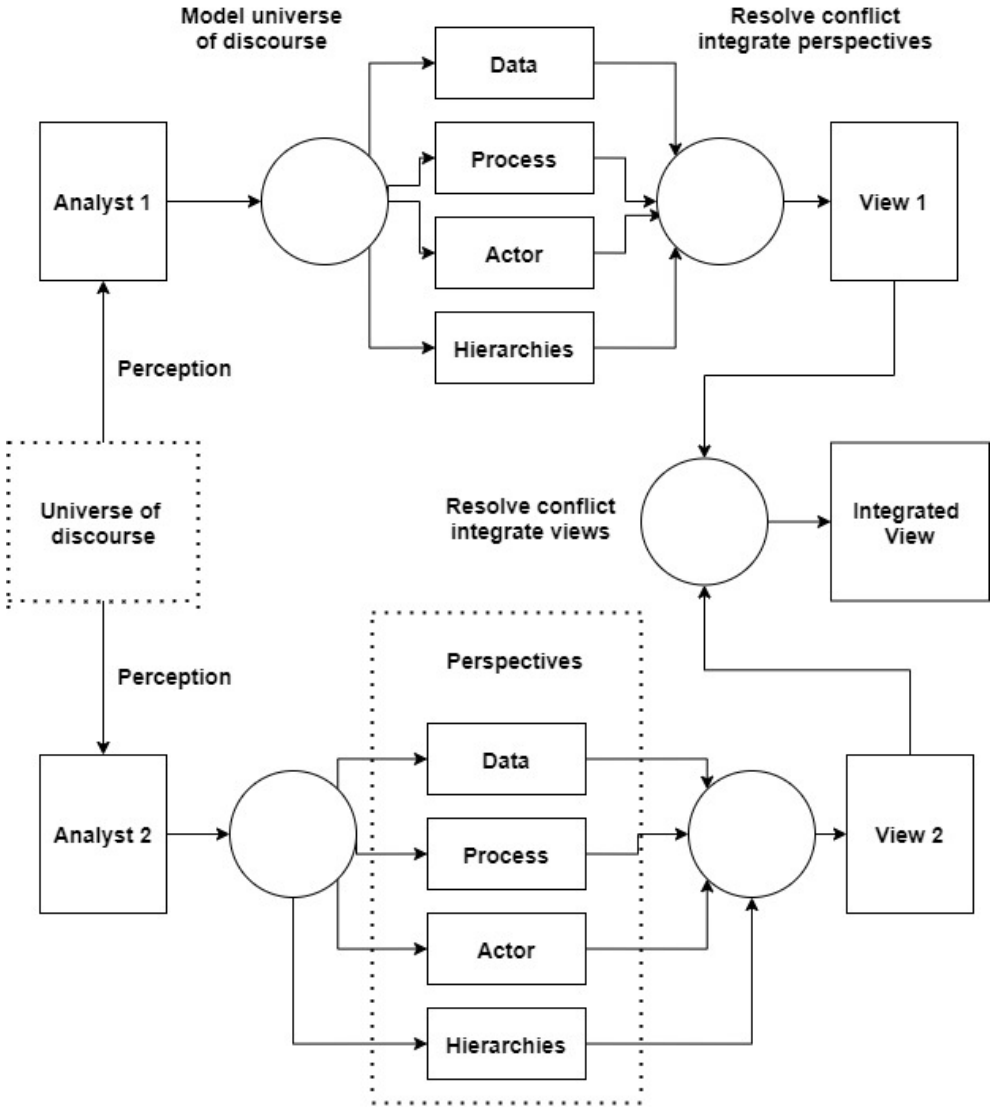

Figure 4.2: Viewpoint Oriented Requirement Validation [2]

viewpoint oriented requirement validation to model the Universe of discourse. In this method, we use two analysts: Analyst1 and Analyst2, as shown in Fig 4.2.

The analyst1 and analyst2 model the Universe of discourse by three perspectives and two hierarchies. The three perspectives are data, process, and actor [2]. The perspectives and hierarchies are analyzed to produce a list of disparities and types of disparities [23]. Then the perspectives are integrated into views view1 and view2. The circles and boxes in figure 4.2 represent processes and, inputs and outputs of processes, respectively [2].

Testing Based Requirement Validation [48] [3] [4]

The testing of requirements is done for requirement validation as it is better to perform it before it is developed into the system [3]. If the process is taken in the early stages of a software development process of a system, it would be less costly [48]. The testing process begins in the requirement phase where there is a high probability of defect occurrence, and it also helps to address the quality of requirements and also to check the incomplete

requirements which are the leading cause for faults in a project [48]. A test case is derived for each requirement for the Requirement testing, and this helps to identify the requirements which are incomplete because it is dicult to derive a test case from requirements that are not complete [3].

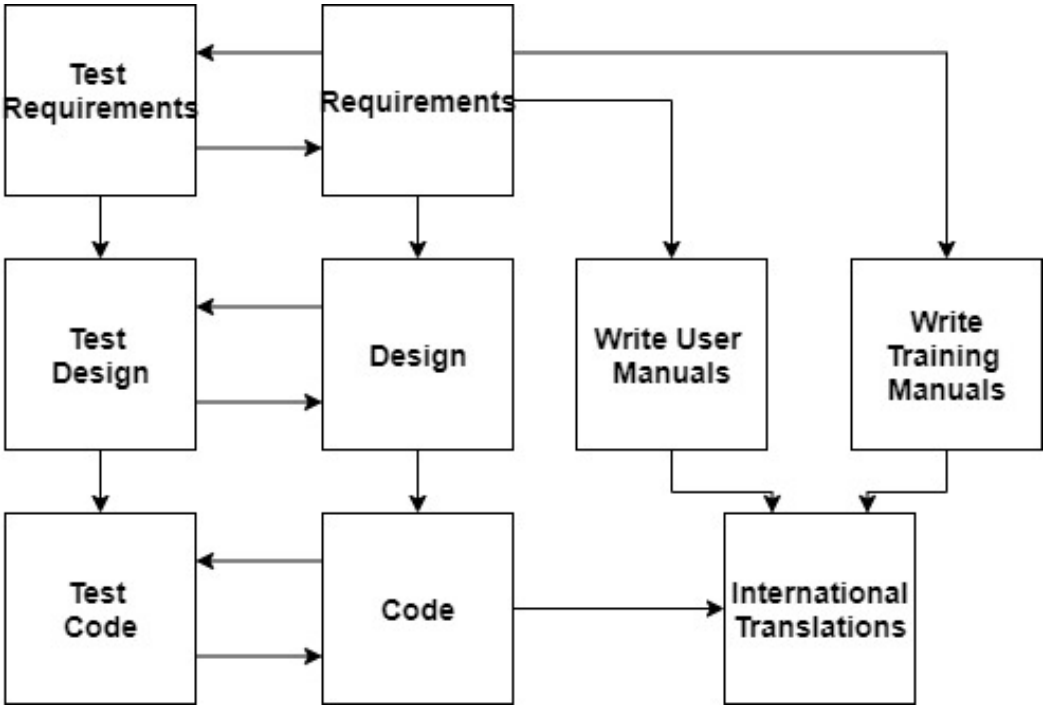

Figure 4.3: Requirement Testing [3]

According to [3], the following are a few characteristics for a good test process.

- **Test must be timely:** When the requirements are first drafted, testing begins, and it has to be integrated throughout the software development lifecycle. The testing has to be early, and it has to be done very often. By this, there will be less stalling in time management [3].

- **Test must be effective:** The approach for the test case design must be comprehensive. Testing should not be an individual task relying on a single person's experience and skill. Still, it has to be based on the repeatable test process as it should produce the same test case for a given situation, and not depending on the individual tester. The test case design should be functional, which has to cover all the requirements [3].

- **Test must be efficient:** The number of test cases produced by the test case design should be minimum, so the time required for executing and managing the tests can be reduced. Testing activities must be automated to allow them to be performed quickly [3].

- **Test must be manageable**: The test process should provide enough data to identify the status of testing at any time. The results of the test process must be predictable, which is the output should be the same at each time when a test is successfully executed [3].

Figure 4.3 shows the working of testing the requirements. Requirements testing is done at the start of the validation process to derive test cases. The people involved in the process are mostly testers and requirement engineers, and the people should have experience with test case design. If the people involved have minimal experience, it may affect the project by cost and time.
There are a few specific techniques that are used in the field of the required testing category. They are:

- **Test case driven Inspection(TCD Inspections):**
  Test case driven inspection is a technique proposed by Tony Gorschek and Nina Fogelström which was used in Danaher Motion Särö AB (DHR) Sweden. The technique is used for requirements testing, and it uses test cases for inspection, and it involves testers in the early stages of the software development process, which is called the pre-project stage [4]. The technique is a three-step process, and the test cases produced in the process are used in the later phases of the software development [4].

  The people with the most involvement in the process are product managers and testers. According to [4], step 1 in the process is to select and review the requirements, and product managers do it, and after the review, few requirements gets disposed. The selected requirements are added to the initial specification

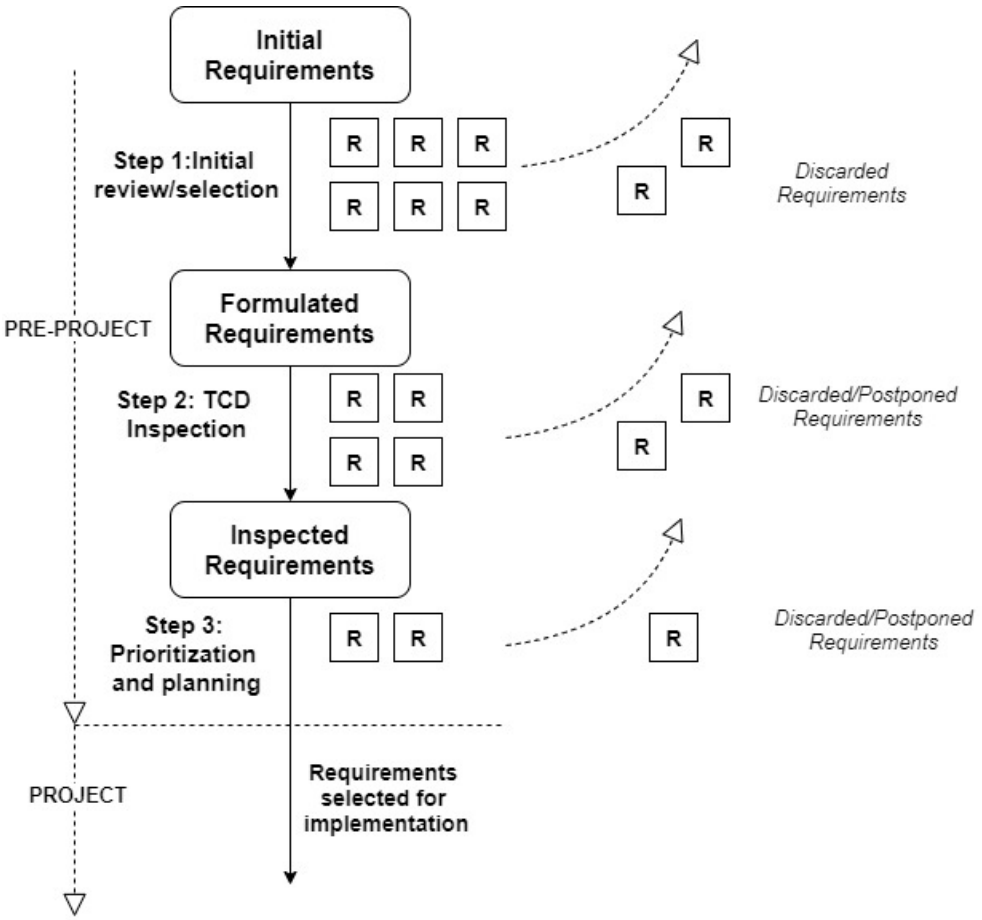

Figure 4.4: Testcase Driven(TCD) Inspection process [4]

The product manager uses his/her personal and also his/her colleague's experience and knowledge from the initial trail of requirements as it is mostly ad-hoc process [21]. After the trail, the selected requirements are specified as attributes and included in a template. The selected requirements are also called as specified /formulated requirements are then later proceeded to step 2 of the process [21].

In step 2 of the process, TCD Inspections are performed where the test cases are created using the requirements [4]. The requirements which are of little priority and are irrelevant to the project are removed in this step.

In step 3, the requirements which are inspected, prioritized and project planning is also performed in this step. In the TCD Inspection process, testers were included in the early stages of the inspection process, and by this, there will be a reduction in the cost for skilled inspectors [4]. A realization has occurred for the product managers working on the pilot study of TCD inspections at Danaher Motion Särö AB (DHR) Sweden, that the processed requirements are of high quality [4].

Model Based Requirements Validation [49]

Model-based validation technique: choosing an appropriate model validation technique is a preliminary exploratory structure decision—the way toward choosing if a given model satisfies its requirements. An executable model provides a standard with to favouring lower level, continuously point by point structure delineations, for instance, source code [49]. Verification and validation are essential for quality management. Regularly, testing tends to as it confirmed the verification meets the details of the specification. By utilizing use case models to make framework tests, this likewise helps with item approval. These use case models allow the description meets the user needs. Use case models improve the requirements to be more testable and write the ambiguities. The test cases generated from the activity diagrams help in specifying a base for test coverage. Utilizing use case models for model-based testing implies we are deciphering the utilization case models with the end goal of test age. It suggests that blunders in the model can forestall the capacity to create tests. Before the test age, we check the model for blunders that would forestall age. We check for blunders, for example,

- Use cases without action graphs
- Activities without changes
- Illegal limitations
- Illegal builds in note revelations
- Missing start/stop steps

Training is necessary for testers while using model-based validation technique other than using simple test scenarios.

Feature Oriented Requirements Validation [50] [51]

A feature is a logical unit which possesses functionality that is understandable to end-customers [50]. The unit is constituted of requirements that are associated with the feature and the behavioural specification of the feature [50]. A set of features are used as a feature

model for product development [51]. A feature validation can be referred to two situations as a structural perspective and a functional perspective. The structural perspective deals with the limitations of the feature model, and the functional perspective deals with the unwanted behaviour from the behavioural specification of the feature [51]. The validation of the feature set is done to increase the confidence by using feature-oriented validation technique. As the Size of feature models grow then the feature set can exhibit flaws that are present in the features which may be dicult to avoid. So, to avoid all these feature interaction problems, the validation of the features is done. In a feature-oriented requirement validation, there are few steps to follow, such as:

- **Feature Specification:**Provides us with the description of the feature in a restricted natural language and later which facilitates us with the transformation of an informal specification of the feature into a formal specification. The process is for the validation purpose, and then it is continued by using the RUCM approach [52] where use cases are used to specify the feature. The process is divide into two steps, such as:
  - **Use Case Identification:** The feature is constituted of requirements and the corresponding behaviours. In this step, the functionalities were split and used to identify the uses cases based on the understanding of feature [51].
  - **Use Case Specification:** the RUCM template is used to fill out the specifications of use cases, and it is done using restricted natural language. A particular set of rules were strictly followed to assist in the analysis [51].
- **Feature Behaviors Formalization** is used to analyze the RUCM templates and formalize the behaviours of the corresponding features by using the extended time abstract State Machine(eTASM) Language [53]. The process consists of four steps, such as:
  - **System Constituents Identification** extracts the relevant system constituents referred in the RUCM use cases and specifies them in eTASM machines [51]
    - **External Constituents Identification:**Use case actors are considered as external constituents which interact with the proposed system. The external constituents will be modelled to simulate the execution scenarios [51].
    - **Internal Constituents Identification:**Each use case is considered to be an internal constituent, making up the proposed system. The internal constituents will be modelled to simulate the proposed system [51].
  - **Constituents Interaction Identification** Identifies the interactions between different system constituents referred in the RUCM use cases and specifies them in eTASM environment variables [51].
    - **Data Transmission Interaction:** represents that data (such as the state information and various sensor values) are transferred from the sender to the receiver, which is modelled as eTASM environment variables [51].
    - **Data Modification Interaction:** represents that the data of the receiver is directly changed by the sender, which are modelled via directly modifying the value of the receiver's environment variable [51].
  - **Machine Rules Specification** Analyzes the possible states of identified machines and specifies feature behaviors by using a set of eTASM machine rules [51].
    - Identification of possible states of the corresponding constituents
    - Identification of transition conditions of states

    * Identification of the actions when the system enters a specific state.
  - **Property Annotation** Adds non-functional property annotations to the relevant eTASM machines [51].

- **Feature Requirements Formalization** is done by modelling the feature requirements by using the Observers Techniques [53] in eTASM for the validation process.
  - **Listener Specification** specifies the sequence of the possible events which represents the proposed system's observable functional behaviours or non-functional properties required by the feature requirements, and the corresponding actions taken on observer variables when a Listener catches the sequence [51].
  - **Observation Specification** formalizes a predicate depending on the ob-server variables. If the predicate of the Observation holds, i.e., evaluates to be accurate, it implies that the property satisfaction of the feature is achieved, as it can be observed in the proposed system [51].
  - **Events Filtering** identifies the interesting events and filters out the irrelevant events by specifying Events Filter [51].
  - **Traceability Creation** links a specific Observer to the textual requirements. The link is used for requirements traceability from the formalization to natural language requirements in order to perform coverage checking [51].

- **Feature Validation** It is used to detect the flaws in the selected features. the section is constituted of performing three kinds of model-based validation checking, such as [51] :
  - **Logical Consistency Checking:** This is performed on the eTASM models by using developed tool TASM toolset [51]. While working with these two inconsistency flaws occur one is that different values are assigned to the same variables by different machines, and the other is two rules in the same machine are simultaneously enabled [51]].
  - **Coverage Checking:** It corresponds to checking that the feature requirements can be integrated feature specifications. If an observation cannot hold, then it exhibits even though the feature specifications satisfy their requirements there are few inconsistencies in the behaviour of integrated feature specification [51].
  - **Model Checking:** it is done to verify that the eTASM model is free of deadlock and whether the eTASM model fulfils an expected property that is specified in the feature specificationl [51].

4.3 Results of the Survey

4.3.1 Demographics

The survey questionnaire was formed by using Google forms, and LinkedIn was used to reach out to the potential participants for executing the survey. The participants we have chosen for the survey are people who have close relations working with the requirements phase. Requirements Engineers, Business Analysts, Project Managers, Product Owners, Domain experts, Tester's, etc. are few participants that are chosen for the survey. We have received a total of 33 responses from the survey.

The survey questionnaire is analyzed concerning the research questions where a set of survey questions gives us the result that we intend for the research question. The following are the research questions with respect to the survey questions that answer them.

Research Question 1: What are the requirements validation techniques currently being practiced in organizations?

Questions 1-3 of the survey gives us the roles, experience of an employee working in organizations. These details help us to validate the results of validation techniques per suppose if any person without experience has entered the details that do not make any sense. From Question 4 of the survey, we have accumulated a list of requirement validation methods were framed as a question.

The percentage of the participants as per their roles are Project Manager 24.2%, Business analyst 21.4%, Requirements Engineer 6.1%, Software Engineer 6.1%, Quality Assurance Engineer 6.1%, Product owner 9.1%, Domain experts 3%, Agile coach 3%, Test Engineer 9%, Developer 3%, Product manager 3%, Test engineer 3%, Test lead 3%. Remaining few roles were selected from the literature review is 85%, and the rest were contacted as per their involvement in the requirement phase. The following is a figure representing the responses regarding their roles.

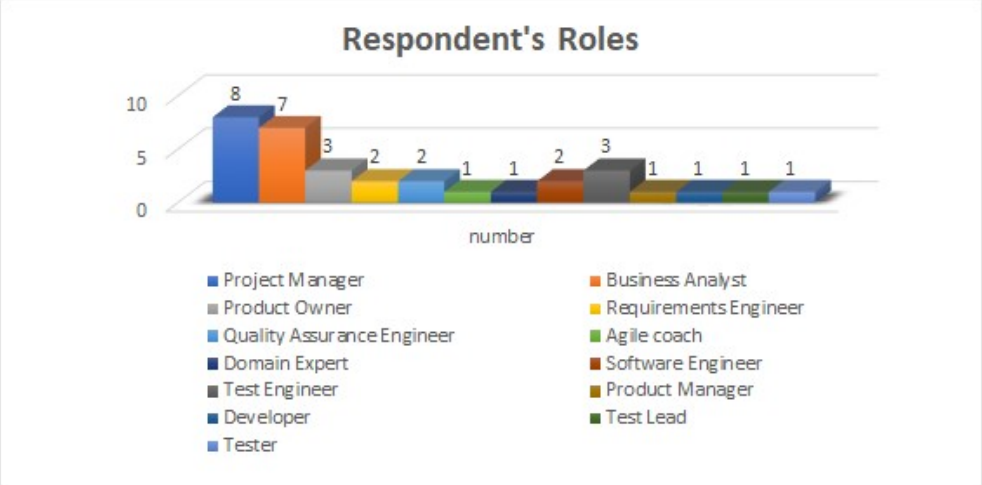

Figure 4.5: Participant Roles

In a total of 33 responses, 27.3% in <1 year; 30.3% in 1-3 years; 21.2% in 3-5 years; 21.2% in >5 years.

Most of the participants have selected two or more techniques and the commonly used techniques are Requirements Reviews, Prototyping, and Specification. The responses for the selected validation techniques are Reviews - 51.5%; Inspection - 21.2%; Prototyping - 54.5%; Model-Based Validation - 18.2%; Viewpoint Based Validation - 15.2%; Testing Based Validation - 45.5%; Feature-Oriented Validation - 39.4% and Specification - 51.5%. The following is a figure showing the results of the question.

The participants that have experienced less than a year who are working as Business Analysts, Software engineers, and Project managers are choosing to work with the techniques

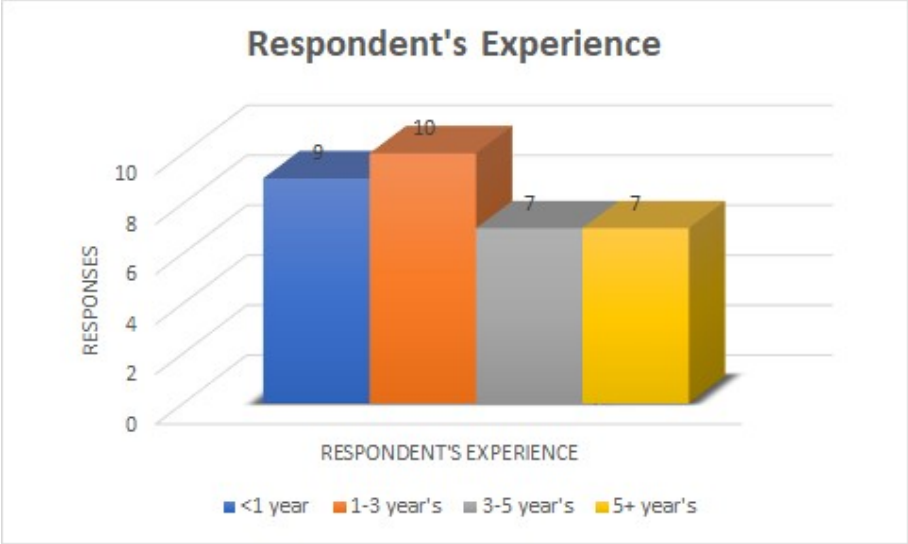

Figure 4.6: Participants's Experience

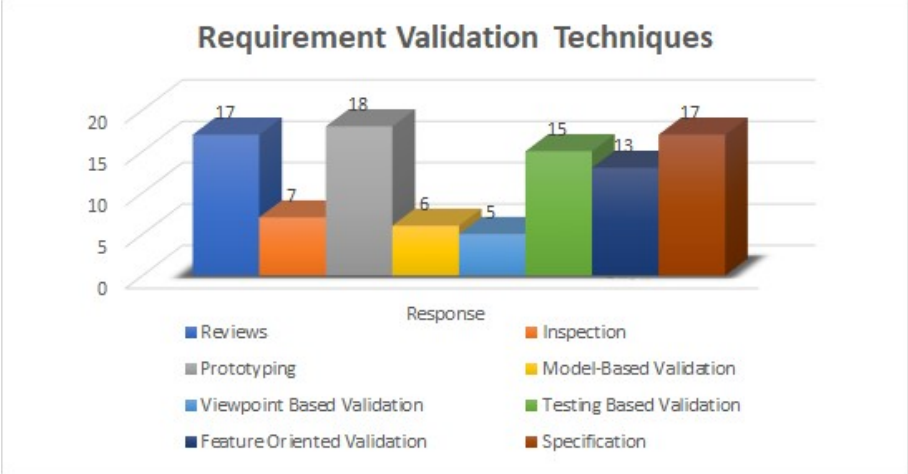

Figure 4.7: Requirement Validation Techniques

that already established in the software industry such as Review, Inspections Prototyping, and Testing Based Validation. The participant's daily deals are with the standard procedures of working with the requirements. The participants who have experienced by one to three years have an operational structure of an experienced way of dealing with the day to day problems that occur with the requirements. The participants with this experience are looking for more than the standardized way to work with requirements, and the techniques they use are Inspections, Prototyping, Model-Based Validation, Viewpoint Oriented Validation, etc. The participants from the experience range three to five years and more significant than five years are on the same level of their working module. The people of both sections deal with similar issues with the requirements and their involvement and experience help them to overcome the issues. The participants of theses section choose to work with techniques as Prototyping, Inspection Review, Feature-Oriented Validation, and Testing Based Validation. All the participants, despite their experience, chose to work with techniques such as Reviews, Prototyping, Inspection, which are most common. These techniques were used for a better understanding of the requirements, and also we can detect

mistakes with the requirements in the project sooner.

From the above inquiry, we get the use of requirement validation techniques in associations. The requirement validation techniques we get from that question are taken from the writing survey. On the off chance that they are utilizing some other requirement validation procedures to get those lists, we have done this survey. Keeping just' different' alternatives at the end in the above inquiry prompts just hardly any prerequisites validation procedures. The other validation techniques we got by this inquiry are Generation of experiments, given when done technique, Product proprietor, Processes and BA, Testing.

Research Question 2: What are the factors that are influencing the selection of requirements validation technique?

The survey helps in gathering the factors list which are having influence in selection of requirement validation technique. The question is open ended and answers from participant to participant showing difference in opinion about factors. The answers are provided in sentence form. After analysing those answers thoroughly, factors list which have influence in selection of requirement validation techniques are derived.

A couple of participants demonstrated that *"Viability, simple affirmation from team"* , *"Contingent upon partner and most effortless method for introducing"*, *"Gantt graph and promotion cycle"* and *"Condition" "We do it along these lines since we have me (a requirements engineer) and a UX originator and the praxis demonstrated that making models or confirming prerequisites with inner/outer Stakeholders by looking into are the acceptable techniques"*. The above reactions show that the variables a couple of individuals consider are Stakeholders that are engaged with the venture, the introduction of the necessities, and the workplace.

A participant referenced *"One factor could be the venture size, the greater and complex, would it be smarter to actualize computerized tests for prerequisites validation, for instance. Another factor could be the motivation behind the product, if it is where the client experience is a crucial factor, at that point the prototyping could be a decent instrument and direct necessities audits"*. The reaction gives us that the task size is the primary factor as it chooses the cost, time, resources, and the unpredictability of the undertaking.

A couple of participants additionally expressed *"Culmination, Consistency, Validity check and Reality check"*, *"Fulfilment and legitimacy checks"*, *"Undeniable nature, dependability, availability"*, *"The centre is consistently to make prerequisites understood so the usage procedure is smooth" "100% requirements inclusion during the validation"*. All the above reactions are about the culmination of prerequisites, legitimacy, and rude awakening of the necessities and these are the factors.

Different participants likewise expressed that *"The most significant factor is that the prerequisites procedure can permit us to adhere to the customer's principles and requests yet besides nearby laws and guidelines. It is particularly significant in the area I am working in."* (Business worth and rules regarding the space of the application), *"The multifaceted nature of the errand to unravel and business esteem (significant/incredulous) of the undertaking." (intricacy of the venture and business esteem) "Certainty, Technical information, understanding organization esteems"*, *"Resources with the correct fitness and experience."* The expressed reactions give us that Business esteem, Domain of the project, experience teams were considered as factors.

Furthermore, a couple of others expressed that *"Get the speculation approved with clients as quickly as time permits. Show early usage, get criticism. Get the opportunity to code as quickly as time permits. Make determinations as tests." "the nature of the result; the quantity of necessities; prioritization" "Prerequisites are ideally converted into computerized testing" "Quick, early, quick input, test-driven turn of events" "Relies upon the client, time period, financial plan, scope" "Posing the correct inquiries to the ideal individuals" "They have to give quick criticism circles." "Time and resources" "Specially appointed".* The above reactions display factors, for example, input from the Stakeholders, time for the fruition of a venture, customers, and clients.

The participants with less than a year experience feel the factors that affect the selection of the techniques are Completeness of the requirements, feedback, presentation, stakeholders, and resources. The participants with this experience think the base factors that tend to affect the techniques are chosen as the factors. The participants with experience of one to three years have chosen Validity checks, Reality checks, Completeness, time, and resources as the factors for the techniques. The participants with experience three to five years and more than five years have chosen stakeholders, Business, Completeness, consistency, and feedback for the project. From all the responses, it is clear that regardless of the experience each participant chose Stake-holders, Business, Feedback, and all as the factors, they have to deal fro the selection of techniques. As the experience of the participant's increase, we see factors that they provided are more complicated. The person with more experience has to deal with the complicated issues, which in turn provide us with a good result.

The requirement validation techniques related to each factor are summarized, as if the same requirement validation techniques mentioned by the various participants for a factor, we consider the requirement validation technique is beneficial in the aspect of the factor. The list of the factors and requirement validation techniques are shown in the below table.

S.No	**Factors**	**Validation Techniques**
1	Time	Reviews, Prototyping.
2	Business	Reviews, Prototyping, Inspection, Model based validation, Testing based validation.
3	Speed	Inspection, prototyping, Reviews, Feature oriented validation
4	Feedback and Involvement of Stakeholders	Feature oriented requirement validation, Reviews, Prototyping, Testing based validation, Reviews, Prototyping, Inspection
5	Requirements Coverage	Testing based validation, Reviews.
6	Test	Prototyping, Testing based validation, Feature oriented requirement validation, Reviews.
7	Resourses and Knowledge	Prototyping, Reviews

8	Size	Reviews, Prototyping, Testing Based validation, Feature oriented requirement validation.
9	Effectiveness	Inspection, Prototyping.
10	Completeness,Validity checks, Reliability	Reviews, Prototyping, Viewpoint based validation Feature oriented requirement validation, Testing based validation

Table 4.7: Validation techniques and Factors.

The table below illustrates the roles of the participants answered the survey questionnaire and have given the factors and critical factors influencing the selection of requirement validation techniques from their experience. A brief explanation of factors was categorised from the individual perspective of the participants in the survey. These results provide mindset of a participant what he or she thinks about what are the factors that have an influence in the selection of requirement validation technique and how the factors are changing role from the role.

S.No	**Roles**	**Factors**	**Critical factors**
1	Business Analyst	Choosing correct people to validate requirements,Customer,Time frame, Budget, Scope, Completeness, Consistency, Validity checks, Client rules and regulations, Stakeholders, Size, Ad-hoc	Time,Business,Size,End-user involvement,Client rules and regulations,Inter-dependencies
2	Project Manager	Feedback, Gantt chart, Hype cycle, Environment, Resources with correct competence and experience, reliability, Cost	Feedback, Delivery, Context and customer, Resources with competence and experience, reliability, Cost.
3	Requirements Engineer	Verifying requirements with internal and external stakeholders, Type of requirement	Roles in the team.
4	Domain Expert	Quality of outcome,Requirements Prioritization	Customer
5	Tester	Business, Traditional project, Relevance, Time, Complexity of the task, Business value, completeness, Validity checks	Business, Knowledge of project management, Intuition, Time, Completeness
6	Product Owner	Stakeholder, Total requirements coverage, Feedback from customers	Stakeholder, Total requirements coverage, Feedback from customers.

Table 4.8: Roles and Factors.

The last list of the factors from the participants provided through the survey questionnaire are:

- Stakeholders
- Project Size

- Customers
- Business Value
- The domain of the project
- Experienced Teams
- Reality Checks
- Validity Checks
- Requirements Completeness
- Feedback
- Time

Research Question 3: What is the factor that has the most effect in selecting a requirements validation technique?

The below mentioned are the list of factors which we shortlisted according to the survey results provided by the participants. Each factor has its criticality, and as we know, we cannot expect to think one factor has the most influence. So, we have chosen to rank the factors based on the participants choice of requirement validation technique. The ranking structure of factors considered by participants views. If a factor is answered more times by different participants we considered them as factors which are more critical.

S.No	Rank	Description
1	Factor Rank = 3	If the factor is provided with the rank 3 its criticality is considered to be high.
2	Factor Rank = 2	If the factor is provided with the rank 2 its criticality is considered to be moderate.
3	Factor Rank = 1	If the factor is provided with the rank 1 its criticality is considered to be low.

Table 4.9: Ranking of Factors.

The ranking mentioned above is developed within the context of our project, and each factor is ranked for the participants' view and also with corresponding to the factors presented in the study. The rank given to each factor by the description of the factor and its effects on the techniques as well as the project. We consider the factors with more mentions by participants have high significance.

S no.	Factor	Rank	Requirement Validation techniques	Description

1.	Time	2	Reviews, Prototyping	Time is an essential factor for every project and it has chosen to be essential with these techniques as these take a lot of time to process.
2.	Business	3	Reviews, Prototyping, Inspection, Model-based validation, Testing based validation	The business model defines most of the project and this affects the choice of techniques to a very high extent for the project to be held up.
3.	Speed	2	Inspection, prototyping, Reviews, Feature oriented validation	Speed is chosen to be a moderate factor as this is dependent on the techniques and each technique runs at its own speed.
4.	Feedback and Involvement of Stakeholders	3	Feature oriented requirement validation. Reviews, Prototyping, Testing based validation, Reviews, Prototyping. Inspection	Feedback and stakeholders involvement is a major factor that influences the project to meet its standards and the factor is considered in all stages of the product development.
5.	Requirements coverage, Completeness, Validity checks, Reliability	3	Reviews, Prototyping, Viewpoint based validation, Feature oriented requirement validation, Testing based validation	The total coverage of the requirements is important in every project and it is essential to maintain the standards of the project.Completeness, reliability, validity checks are the most expected things expected from requirements validation.
6.	Test	2	Prototyping, Testing based validation, Feature oriented requirement validation, Reviews	Test is chosen to be a factor which is moderate and as it is only used in a few techniques to fulfill the requirements.
7.	Resources and Knowledge	3	Prototyping, Reviews	The knowledge of the topic that we chose to turn into a project is important to make it viable and also the resources that need to be used.
8.	Size	2	Reviews, Prototyping, Testing based validation, Feature oriented requirement validation	participant referenced the size of the project important because, since the start of the task individuals need to consider the size of the project in most aspects. Size of the project decides how they are going to lead the requirements validation.

9.	Effectiveness	1	Inspection, Prototyping	participants referenced that survey and input from partners are significant because they recognize what is significant for validation. A participant referenced that the client is significant with regards to validation since he/she recognizes what he/she needs. Various participants referenced the end client since he/she is a specialist of an area, and he can check prerequisites that are reasonable to the undertaking—our supposition about partners as the fundamental factor in choosing a prerequisite validation procedure.

Table 4.10: Ranking and Description of Factors

The summed up essential components from the assembled reactions are Inter-dependencies, Feedback, Testing, Teamwork, Time, information, Customer, Size, Business, End-client inclusion, Business worth and exertion, Test, Time and asset accessibility, Delivery, Stakeholders, Intuition, Time and Business, Reliability, Resources, Test cases. Among this rundown, we believe the overview results in Time and Business are the essential components. The purposes behind choosing these variables for the underlying factor are these two factors at whatever point they are referencing endeavours, resources, Delivery they are relating with time as the primary factor. Business is identified with the variables they have referenced like dependability, experiments, End-client contribution, Stakeholders, Resources.

Participant furnished a response dependent on the product improvement system he is following. *"While utilizing the nimble procedure, they need to ensure everything is working right off the bat, and they go on more subtleties."* He did not give the motivation to why he thinks it is the primary factor and the appropriate response he gave depends on one anticipated system, so we did not think of it as much for the outcomes. *"Time criticality and business esteem"* is a significant factor as per him. They did not give the motivation for picking them as the primary factor.

On account of another participant *"Speed and time are the basic components and validation of prerequisites that should be done rapidly."* The purpose behind speed and time is the taken necessities get obsolete. As indicated by this participant, *"Stakeholders are the significant factor." "Guide the requirements and test it is significant."*, and Delivery is additionally viewed as a factor since when a user does everything rapidly, the unjust suspicions are assessed early, and the expense of fixing them is anything but dicult to fix, and it states time as a factor—Timespan since it is significant in Business.

A couple of reactions are, for example, *"Jobs in the team because with no job, the validation is deficient." "Authenticity checks, Usability, and unwavering quality of necessities." "Business worth and exertion required, the money related segment has a ton of laws and*

guidelines to follow." Business esteem is viewed as the most significant factor in picking a validation strategy. *"Criticism and utilization from clients and Stakeholders since when they see and utilize early models"* and by these, we know the significance of the prerequisites. *"Dependability End-client inclusion because an end-client might be a specialist in his her explicit space yet probably will not be a specialist in software engineering."* So, we should approve if it is substantial as far as ease of use and sufficiently genuine.

Different reactions are, for example, *"Setting and client in light of the fact that the client realizes what he needs." "Testing it makes validation OK." "Resources with right skill and experience because any team searching for gifted individuals in this specialized world, Intuition since with regards to item improvement, it is about nonstop item disclosure, so instinct with bits of knowledge is the best device to approve the prerequisites" "Size of an undertaking in light of the fact that since the start, the task individuals need to consider the size of the venture for some things. One of them is the means by which are they given to lead the necessities validation on the off chance that the venture is excessively little?" "Prototyping or basic experiments following acknowledgment rules could be sufficient." "However on the off chance that it is a significant task with a ton of structures or a wide range of work processes accessible for the end-client, at that point the appropriate response here could be to execute the age of experiments yet utilizing robotizing procedures since later could be unmanageable trying many prospects." "Time and asset accessibility since that is the way the plan of action runs."*

The participants were asked to provide the factors they think are the most critical that affect the techniques and the responses were analyzed and classified into sections. The participants with higher experience have responded with Stakeholders, Business, and Size of the project and the participants with lesser experience have provided with the time and resources.

Validation techniques and related factors:
From the participant results, we have analysed the validation techniques and the factors related to those requirement validation techniques. The relationship between requirement validation techniques and factors is mentioned below. The data illustrates how the factors influence the validation techniques.

- **Reviews & Inspections:** The review and inspection are a software development process where a group of stakeholders were assembled to collect and work on the requirements of a software project. The process has to consider several factors to create the project and make it prizewinning. The review and inspection is time taking processes which require a lot of human resources as every aspect of the project have to be discussed and also the size of the project has a significant effect on the time and need of workforce. While working with these techniques on the requirements, multiple feedbacks were taken into account from the stakeholders, and several tests are done to the requirements to know the necessity and value of it in the project. The stakeholders working on the requirements should retain the required resources and the knowledge to use the resources to maintain the completeness of Requirements. The survey has shown us the factors considered to work with the Review and Inspection. The factors are such as Time, Feedback and Involvement of Stakeholders, Requirements Coverage, test, Size, Resources and Knowledge, Validity, Effectiveness.

- **Prototyping:** Prototyping is a process of iterative development of software until the desired functions are performed. Every requirement was developed in the product

to make it complete, and through every iteration, the effectiveness of the product increases through the feedback of the earlier iteration. So, the factors that influence the technique are Completeness, Effectiveness, Size, Resources and knowledge, Test, Feedback, Speed, Business and Time.

- **Model Based Requirement Validation:** Different models are used for the Requirement validation in this technique, and most of the times the models depends on the domain of the project and this type of business defines what sort of model should be considered to fulfil the requirements. The factor that is compatible with this technique is business.

- **Testing Based Requirement Validation:** A test case was derived for each Requirement for the Requirements testing, and these test cases help us to identify the incomplete Requirement. The testing based validation takes place in the early stages of the Requirements phase, and if a requirement feels incomplete, the feedback was taken from the stakeholders, and the necessary changes are done to complete the requirements. The increase in reliability of the requirements and the process is also affected by the size of the project, as the size increases the no. of Requirements to fulfil the project also increases. The factors that influence the testing based validation are Business, Feedback and involvement of stakeholders, Requirements Coverage, test, size, completeness, validity checks, reliability.

- **Viewpoint Based Requirement Validation:** The validation process is taken forward by working through the viewpoints of the project through particular perspectives. Each viewpoint holds an individual perspective, and these perspectives define the workings of each requirement, and one requirement can hold several viewpoints which fulfil the function of the requirement. The factors that are considered for the technique are Completeness, Validity checks, Reliability.

- **Feature Oriented Requirement Validation:** A feature is a logical unit which possesses the functionality of a requirement and the validation in the feature-oriented validation is performed as structural perspective and functional perspective, where structural deals with the limitations of the feature and the available deals with the behaviour of the feature. The set of features are used as a feature model for product development as the size of the feature model increases the flaws in the feature set [45]. The validation provides input on the requirement by knowing its limitations and its behavioural standards. The factors that are considered to work with the feature-oriented validation are completeness of the requirements, validity checks, reliability, size, test, speed.

Every participant has referenced their fundamental factors list among those some are repeated. Some factors are furnished with indistinct portrayals of the motivation behind why it must be considered as the most fundamental factor. Rehashed factor reasons are summed up to the factor.

- **Time:** Participants cited that time, speed and conveyance are significant as the time changes the prerequisites are Out-Dated and other participant has said that when the mistakes are discovered early then the cost of fixing and exertion expected to fix the blunders is less. The other participant referenced that Business requires speed. Our conclusion about time as a factor in choosing a validation procedure with regards to the choice of prerequisite validation strategy time is considered intermittently.

- **Business:** Participants referenced that the Financial division has such vast numbers of laws and guidelines to follow while picking a prerequisite validation strategy. Our conclusion about Business as a primary factor in every association's fundamental intention is working together, planning Validation dependent on the Business.

- **Stakeholders:** Participants referenced that survey and input from Stakeholders are significant because they recognize what is significant for validation. A participant referenced that the client is significant with regards to validation since he knows what he needs. Various participants referenced the end client since he is a specialist of a particular area, and he can check prerequisites that are reasonable to the undertaking—our supposition about Stakeholders as the fundamental factor in choosing a prerequisite validation procedure.

- **Resources:** According to a participant resources with right ability and experience are the primary variables while picking a requirement validation technique because at present in this opposition a large portion of them need to be top by having specialized staff. A participant has referenced that instinct since with regards to item improvement; it is about nonstop item disclosure. Hence, instinct with bits of knowledge is the best device to approve the prerequisites.

- **Size:** Participant referenced the size of an undertaking because since the start of the task individuals need to consider the size of the venture for some things. One of them is how are they going to lead the prerequisites validation on the off chance that the task is excessively little? Prototyping or basic experiments following acknowledgement rules could be enough. In any case, why on the off chance that it is a significant undertaking with plenty of structures or various work processes accessible for the end-client? At that point, the appropriate response here could be to actualize the age of experiments yet utilizing robotizing procedures since later could be unmanageable trying many prospects

Chapter 5

Discussion and Validity Threats

5.1 Discussion

Our research is about the factors that influence the selection of requirements validation techniques and analyzing the factors with more impact. Prioritization of factors helps to generate the quality output. We made the hypothesis by analyzing the factor with more influence in the selection of requirements validation techniques. We made objectives based on our aim and formulated the research questions. Discussions of our research questions are discussed here.

RQ1: What are the requirements validation techniques are currently being practiced in organizations?

RQ1's research aim is to enlist all the validation techniques that are currently practised by the organizations and also to learn more about the new techniques they are using in the software industry. To answer this research question, we have conducted a literature review and survey to get the requirement validation techniques that are currently being practised in organizations. A literature review helps us in taking the list of requirements validation techniques that are presently being practised in industries. From the literature review, we have selected 253papers for the study and chosen 27 papers for the final consideration from checking of abstracts and everything two articles have been finalized for our study as our start set to get the requirement validation techniques list.

Literature review gives requirement validation techniques that are researched and presented in the literature by various authors. This list from the literature helps in validating the survey results. The validation techniques we got from the literature review are Requirements inspection, prototyping (prototyping works in two ways throw away prototyping and Evolutionary prototyping), Viewpoint requirement validation, Testing based requirement validation, Feature oriented requirement validation. Some of these requirement validation techniques from the literature have various methods of doing it. Example in testing-based requirement validation Test case driven inspections is used to validate the requirements. In feature-based requirements validation feature specification, feature Behaviours formalization, Feature requirements formalization, Feature validation are the methods. From the survey, the participants have presented the requirement validation techniques directly. We focus on displaying the list of requirement validation techniques that are proposed by them.

RQ2: What are the factors that are influencing the selection of requirements validation techniques?

RQ2's research aim is about gaining the knowledge of factors for the techniques in the selection process. The research method that has been used to answer the research question is a survey. The survey is prepared by using the Google Forms, and it is sent to all the professionals working in and with the requirements field through the online platform, i.e., LinkedIn. The survey questionnaire is used to collect all the necessary data on the factors.

participants have presented their views about factors that influence requirements validation techniques. The answers they have written are in the form of sentences, we analyzed those sentences and documented the results. From the literature review, we have collected a total of 40 factors among those 40, 4 factors are repeated, and a total of32 unique factors we got from the literature. Among those factors, 24 factors are technical, and eight factors are non-technical. Using literature, we have gathered various factors and shortlisted them they are Completeness, consistency, Customer needs, Business plan, Ambiguity, People available, Knowledge of staff, Defect detection, Defect collection, Defect correction, Size, Reuse according to Raja et al.. [21] Cost, Time, changes, Understand-ability, Business plan, Traceability, Coverage of requirements by different roles according to Maleem et al. [20]. Validity checks, Consistency checks, Completeness checks, Realism checks, Verifiability according to Bilal [54]. Customer needs, Clear requirements, Identify missing requirements, according to lee [34]. Completeness, Comprehensibility, ranked for importance, Right level of detail, Traceability according to Felderer [55]. Missing information, Coverage of requirements from different views, Correctness, Completeness according to J. C. S. P. Leite [23]. Importance of test content, Requirements coverage, Software defect number, Test time according to Yao Yujie [56]. These collected factors are used to get knowledge and used for verification of survey results.

We use a survey to collect the factors by participants which they consider during selection requirement validation techniques in organizations.

RQ 3: What are the factors that has the more influence in selecting a requirement validation technique?

RQ3's research aim is to know the influential factors in the selection of the validation techniques and the factors the people deal with while working with the techniques. The research method that has been used to answer the question surveys. The survey questionnaire is used to collect the data of the most influential factors and their description. A wide array of responses have been obtained, and most of the responses are defined in long sentences. The responses are later analyzed and documented to the known and possible factors. An open-ended question is presented in the survey questionnaire to describe the influence of the factor and the working nature of it to understand the importance it possesses towards the validation techniques.

The responses that we have received are staging towards a long list of factors accounting fora forty in number, most of the factors are sub-parts of the main topic. Narrative analysis is used to analyze all the responses and to describe the meaning of the responses that are gathered by the survey questionnaire. After a careful analysis of the responses and the provided description for each factor, we have classified all these responses into five major factors. The five major factors are Time, Business, Stakeholders, Resources, and Size of

the project. The responses are later compared with the responses to analyze and confirm that it belongs to a single major factor. A clear description of all these factors is provided in the Results and Analysis section.

The research question helps us to gain the required information on the factors that are being considered while proceeding with a requirements validation technique.

5.2 Threats to Validity for the Survey

5.2.1 Internal Validity:

The validity threats in this research method were the formulation of the string and the exploring for relevant literature articles. The formulation of the search string is the most critical and crucial task for a research topic which can end in affecting the gathered results. If the research string or the search string is improper or inappropriate, then the articles for the research will be irrelevant. Therefore, proper measures were taken for the formulation of the search string. A search string was created in such a way to acquire all the relevant papers and was verified by the authors and the researchers thoroughly.

The search for the articles related to the study was one of the crucial tasks after the formulation of the search string is done. There were only a few articles on the factors influencing the requirements validation techniques. So, with the acquired articles, the snowballing procedure was conducted to extract all the possible and relevant articles from the database. Based on the knowledge from the literature review, a survey was conducted. The articles were considered by cross-examining between the authors and with the help of the supervisor.

From the knowledge attained from the literature articles, a set of questions were formulated for conducting a survey. If the survey questions are inappropriate, then there is a chance of wrong interpretation of the questions for the participants while answering. Therefore, the survey questions were formulated in such a way so that the practitioners answering the survey could easily read and understand and give appropriate results. The questionnaire was reviewed by the supervisor and cross-checked by the authors while sending the survey link to the practitioners.

5.2.2 External Validity:

Based on the results obtained from the literature review survey questionnaire was formulated. The survey is considered to receive answers from different practitioners having different perceptions of the research study. Sending it to various practitioners will result in improper results and will not be useful for the study. So, with the help of the supervisor, the practitioners were chosen suitable to answer the survey, which helps in better results for the research study. The results need opinions of participants from various companies because the same company people provide similar kind of results. It does not give us relevant results for our research. We need different opinions and perspectives regarding requirement validation techniques and factor that influence the selection of them. So, while sending the survey request, we sent by checking the profiles of participants to get different opinions from various organization people. We selected the participants who are working in the requirements engineering field, business field and the practitioners practising the agile methodology. The survey questionnaire was formulated in an online platform such as Google Forms, and the

questionnaire link was sent to the practitioners through online platforms such as LinkedIn. If the questions were difficult to understand or unable to answer, the practitioners' doubts were clarified immediately about the study to extract some quality data from them.

5.2.3 Construct Validity:

The threats in construct validity were improper understanding and knowledge of the questionnaire revision before it is shared. With the help of the supervisor, the survey questionnaire was revised appropriately and cross-checked for grammatical mistakes. Based on the feedback given by the supervisor on the questionnaire, the questions were re-formulated, and a pilot survey was conducted among the authors.

5.2.4 Conclusion Validity:

The conclusion validity consists of two characteristics or contexts such as quality and trustworthiness. For attaining these two characteristics in the answers obtained from the survey, narrative analysis was considered for the questionnaire. As the research survey is of open-ended and closed-ended questions, narrative analysis is used for the open-ended questions as the information exists about the factors influencing the validation techniques.

5.3 Limitations

Our research is about factors that influence the selection of requirement validation techniques and evaluating the critical factor from the collected results. The research needs opinions of experienced persons about what are the factors and how they recognise the influencing factors in the selection of requirement validation techniques. The results we have gathered and interpreted in this project are based on questionnaire perspectives. It does not include much counters and encounters in opinions. We were not able to verify the results as it was not an experiment, and also the survey is only done in one country as when the results are compared to a worldwide survey it may differ. A clear description of the techniques is not provided in our survey questionnaire, and this may confuse the participants in choosing the techniques they work.

Chapter 6

Conclusions and Future Work

6.1 Conclusion

Selection of suitable requirement validation techniques is more important to reach customer expectations. From our research we have obtained the most influential factors in selection of requirement validation techniques.From the list of factors we mention the requirements validation techniques related to those factors.

We consider the requirement validation technique is beneficial in the aspect of the factor during the validation. Based on the results, we consider time, business and size of the project are considered as the factors which are having a significant impact in selection requirement validation techniques.

6.2 Future Work

In this research, we have identified that while working with validation techniques, a set of factors are considered. There is no further discussion provided on how the domain of the project affects the validation techniques, and the sample size of our study is a little small, as the study is only conducted in Sweden. By considering the issues mentioned above the future work from the study can be, The survey can be conducted from a bigger sample size from various countries; The research on the techniques is to be done based on the domain of the project.

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Appendix A

Survey Questionnaire

Requirements Validation Techniques and Factors affecting them:
The main goal of this research is about factors that influence the selection of Requirement Validation Techniques. We want the user to answer our Survey with the user's experience, which can be very helpful for collecting data in our thesis.

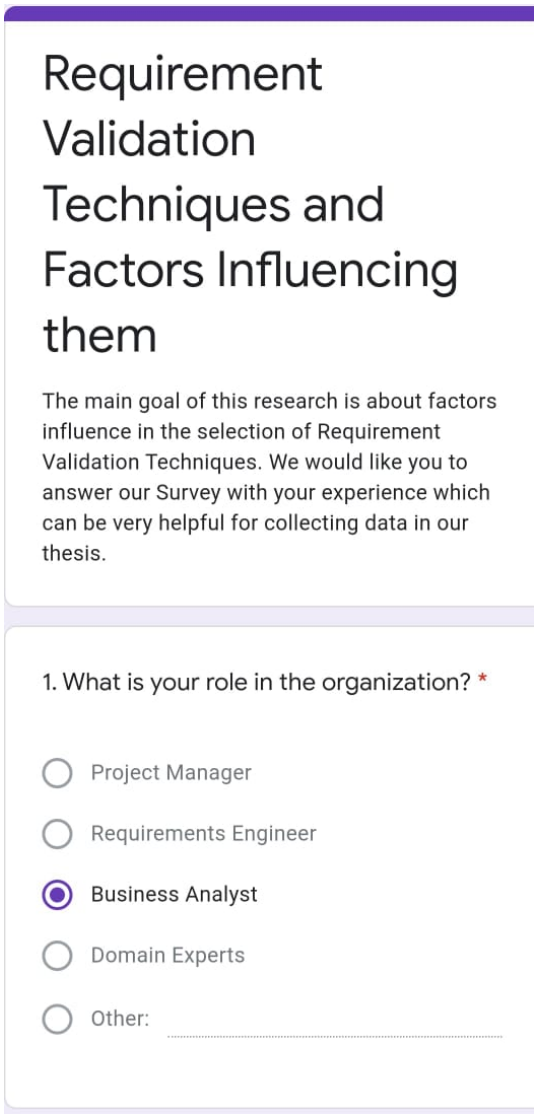
1. What is your role in the organization?*
    - Project Manager
    - Requirements Engineer
    - Business Analyst
    - Domain Experts
    - Other
2. How long you have been working in this organization with requirements?*
    - <1 year
    - 1-3 years
    - 3-5 years
    - 5+ years
3. Can you give some description about how your role involves in requirements phase?*
4. What are the requirements validation techniques used in your organization?*
    - Reviews
    - Inspections
    - Prototyping
    - Model Based Validation
    - Viewpoint Based Validation
    - Feature Oriented Validation
    - Testing Based Validation
    - Specification
5. Can you list, If you are using any other requirements validation techniques other than from our list?*

6. What are the factors do you consider for the selection of requirements validation techniques?*
7. Write down the most critical factor that influences the selection of requirements validation techniques?*
8. Please provide some description of why those factors have the most affect in the selection of a requirements validation technique?
9. Please provide your contact information for further queries?

Appendix B

Survey Results

A survey result is provided below to get an overview on how the participants answered the survey.



Requirement Validation Techniques and Factors Influencing them

The main goal of this research is about factors influence in the selection of Requirement Validation Techniques. We would like you to answer our Survey with your experience which can be very helpful for collecting data in our thesis.

1. What is your role in the organization? *

- ○ Project Manager
- ○ Requirements Engineer
- ◉ Business Analyst
- ○ Domain Experts
- ○ Other: .....

2. How long you have been working in this organization with requirements? *

- (●) <1 years
- ( ) 1-3 years
- ( ) 3-5 years
- ( ) 5+ years

3. Can you give some description about how your role involves in requirements phase? *

Right now I am involved in two projects where I am part of creating a model for a new way of working more effectively. To do this I need to gather requirements from the clients which I do from interviews and meetings onsite.

4. What are the requirements validation techniques used in your organization? *

- [x] Reviews
- [x] Inspection
- [ ] Prototyping
- [x] Model-Based Validation
- [ ] Viewpoint Based Validation
- [x] Testing based Validation
- [ ] Feature oriented requirement validation

5. Can you list, If you are using any other requirements validation techniques other than from our list? *

No other techniques

6. What are the factors do you consider for the selection of requirements validation techniques? *

The most important factor is that the requirements technique can allow us to follow the clients rules and demands, but also local laws and regulations. It is especially important in the sector I am working in.

7. Write down the most critical factor that influences the selection of requirements validation techniques? *

Same as above

8. Please provide some description of why those factors have the most affect in the selection of a requirements validation technique? *

The financial sector has a lot of laws and regulations to follow. Therefore this is the most important factor to consider when choosing validation technique.

Faculty of Computing, Blekinge Institute of Technology, 371 79 Karlskrona, Sweden