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Requirements Validation Techniques practiced in industry: Studies of six companies

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ABSTRACT

Requirements validation is a critical phase of requirements engineering processes, which makes sure that requirements are correct, consistent, complete and accurate. Requirements validation is used in determining the right requirements, while verification determines that implementation is correct with respect to its requirements. The main objective of validation is to certify that requirement specification document is the acceptable description of the system, which is going to be implemented. Requirements validation techniques (RVTs) play pivotal role to detect possible defects in the requirements. RVTs can help in the completion of projects, within given schedule, budget and according to the desired functionality. The studies of six companies regarding requirements validation, is presented in this thesis. This study explores the requirements validation techniques that are presented in academia and practiced in industry as well. Interview studies are conducted in two countries, which is an attempt to find the usage of requirements validation techniques in both of the countries. The pros and cons of identified RVTs are discussed, along with it; the comparison of different RVTs with respect to the satisfaction level of specific RVT in terms of catching defects, time/schedule and cost is presented as well.

Keywords: Requirements validation, RVTs (requirements validation techniques), SDLC (software development life-cycle), GUI (graphical user interface), Requirements Reviews, Prototyping, Testing-based and Model-based RVT.

CONTENTS

1. INTRODUCTION

Requirements engineering is the systematic and repeatable activity of discovering, analyzing, documenting, and maintaining a set of requirements for the development of a computer-based system [1]. The requirements engineering process can be seen as a set of activities containing the structure of each and every activity. These activities are carried out, for example: who will be responsible for each and every activity, inputs required for an activity and output generated from that activity etc. According to Leite et al. [2], "The whole process of requirements engineering is a web of sub-processes, and it is very difficult to make a clear distinction between them". The common consensus is that the traditional bespoke requirements engineering consists of five main process areas, as given in Figure 1: elicitation, analysis and negotiation, documentation, validation, and management.

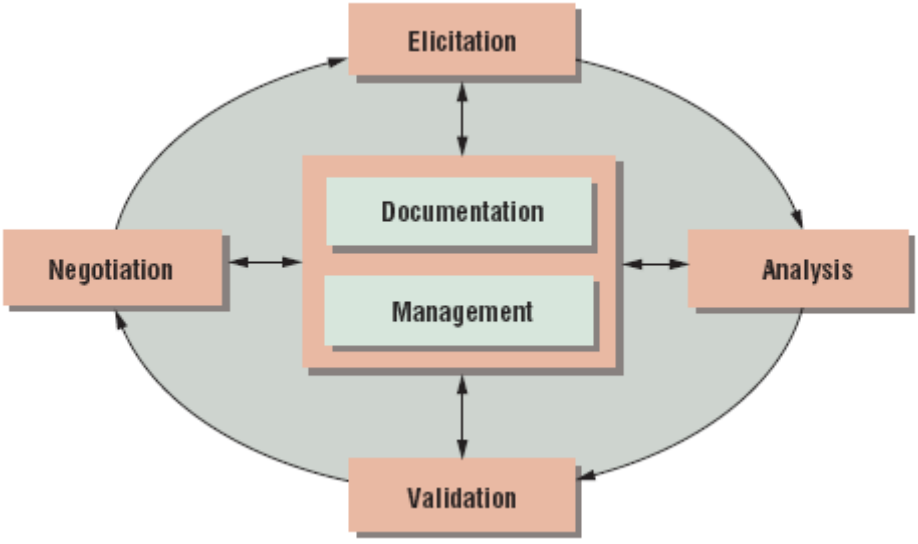


Figure 1 - Requirements Engineering Processes [4]

Requirements elicitation is the basic essential human activity, which encompasses the activities of capturing, discovering, and attaining the requirements from system's stakeholders [3]. The process of *analysis* is very important for discovering unavoidable conflicts between requirements where as *negotiation* with customer is necessary for coming on mutually agreed requirements for the system. *Documentation* of the requirements plays pivotal role in software development which is crucial to document agreed requirements at an appropriate level of detail [4]. *Requirements validation* is concerned with assuring the consistency, completeness, and accuracy of the software requirements [1]. *Requirements management* manages the changes in already agreed requirements during the system and software engineering processes [1].

According to literature [5-6], validation is concerned with determining if requirements are the right requirements and requirements verification is concerned with that implementation is correct with respect to its requirements. For instance, requirements for specifying a system that decreases entropy[1] without expenditures of energy, it means requirements are not valid

[1] Entropy is a measure of unavailability of a system's energy to do work. Entropy is used in thermodynamics that is a branch of physics [7].

and the project has to be stopped. The example of invalid requirement is taken from Bahill et al. [5], which is for an electric water heater controller that is following:

> "If temperature is higher than 70 and less than 100, then output should be 3000 watts"

This system requirement is incomplete in a sense that what should happen if temperature is less than 70 and requirements is inconsistent in a way that what should happen if the temperature is higher than 100. The requirement is incorrect because the unit of temperature is not given, it will be in degree Centigrade of degree Fahrenheit?

Requirements validation is one of the most significant and critical part of the requirement engineering. The main objective of validation is to certify that requirements specification document is the acceptable description of the system which is going to be implemented [1]. According to Bahill et al. [5], The process of validating the requirements ensures three things: (a) "the set of requirements is correct, complete, and consistent", (b) a model for satisfying the requirements can be created, and (c) "a real-world solution" for testing the requirements can be built to make sure that requirements are satisfying the stakeholders' needs.

If software requirements specification document consists of ambiguous, inconsistent, incomplete and inaccurate requirements then it can cause a number of problems for the completion of software project. One of the problems can be delay in the project due to implementation of poor requirements, which may require extra time, resources and budget to complete it. According to Mogyorodi [8], as we have only few deliverables during the requirements phase of the software development the cost of fixing defects in the early stages is lowest. Cost of detecting and repairing errors in the later stages of software development life cycle (SDLC) is more than the defects detected at early stages. According to Davis [9], several studies (as mentioned in his book) are related to requirements problems, for example: poor understanding and communication problems cause 46 % of all the errors, 48% of all the problems experienced in SDLC are related to the requirements.

Requirements validation is very important process especially in case of critical systems where we cannot afford problems. Critical systems are generally embedded systems, which are in-charge of supervision, signaling, or controlling tasks; these activities are performed by interacting with their environment through sensors and actuators [10]. For example: computer based control system for operation theater devices, or a computer based railway crossing are critical systems. Thousands of people's lives may depend on these systems. Requirements for these systems should be properly validated according to their particular scenarios. The cost of finding and fixing requirements problems makes difference here. According to Boehm [11], finding and fixing cost of requirements problems is one hundred (100) times more expensive after delivery of the product as compared to during requirements and early design phases.

Some of the requirements may be perceived differently by different people, for example: "GUI will be user friendly", this sentence can be interpreted in many ways, like: layout of the system should be easy to understand, it could be interactive, it might be attractive etc. For this reasons, it is necessary to validate the requirement to make sure that requirements are correct, clear and consistent. In the world of global software engineering where companies have development efforts distributed not only over development sites but also countries and continents, it is important to gauge if the same understanding and techniques are employed over these boundaries.

The requirements validation techniques which are used in distributed development environment can be perceived differently by different people. This difference can be due to their attitudes and cultural environment. Sometimes, we have more than ten thousand

requirements, in this situation when we apply the requirements validation techniques, it simply collapses. If all the stakeholders of software project are doing the right job but requirements included in SDLC are not properly validated then still project could be unsuccessful [12].

According to Firesmith [13], incorrect or poorly-specified requirements create many problems during system integration, operational testing, manufacturing or deployment of the system. Requirements are not always properly validated by their stakeholders; as a result end product is not acceptable for most of the stakeholders, even if it is verified by testing department. Fixing of requirements problems may have negative impacts on schedule and cost of the project, and some functionality may be missing upon release.

Organizations are facing problems in validating the requirements due to limited time and other considerations; validation of requirements is done in-formally either on ad-hoc bases or simple peer reviews [13, 14]. The selection of appropriate requirements validation techniques (RVTs) for validating the requirements is very important. Due to inappropriate selection of RVTs, companies are facing problems in detecting the defects at early stages of SDLC. The usage of appropriate RVTs can help in completing the projects within given schedule, budget and according to desired functionality.

1.1 PURPOSE STATEMENT

The purpose of this thesis is to explore requirements validation techniques available in academia as well as used in software industry. This thesis work comprises the study of identifying the RVTs, their pros and cons, and how requirements validation attitudes differ in different software organizations. This involves the study of validation techniques already in use and to identify the perceptions problem for these existing RVTs. It also identifies the future research in this area. To make this work more practical, interviews conducted from project managers of different software organizations in Sweden and Pakistan. This thesis can help companies to improve their requirements validation processes by giving information about suitable RVTs according to their needs.

1.2 AIM AND OBJECTIVES

The aim of this thesis is to identify requirements validations techniques practiced in software industry. The procedure for achieving our aim is following:

a. An interview study is performed in industry for establishing state-of-the-art to gauge which RVT used in today's industry.

b. The interviews are conducted in two countries, Pakistan and Sweden. The goal is to gauge differences in validation attitudes if any, in addition, to gather data about what specific techniques are used in general.

c. The perceived problems and shortcomings of used techniques, as well as the general problems conveyed through the interviews are analyzed.

The overall goal of this thesis is to suggest possibilities for future research, in the context of improving validation techniques, the usage of these techniques, and ultimately a report on differences in different software companies in relation to the subject studied. To accomplish this aim, following objectives are required to be fulfilled:

1. Identify the requirements validation techniques, which are practiced in software industry.

2. Identify the pros and cons of the requirements validation techniques.

3. Comparison of the requirements validation techniques used in various software organizations.

4. Differences between requirements validation techniques used in various software organizations.

5. To suggest the possible future work in requirements validation techniques.

1.3 RESEARCH QUESTIONS

For the accomplishment of above mentioned objectives following research questions are required to be explored:

RQ1. What are the requirements validation techniques presented in academia?

RQ2. What are the requirements validation techniques practiced in software industry of Sweden and Pakistan?

RQ3. What are the pros and cons of requirements validation techniques used in software industry?

RQ4. What is the comparison of different requirements validation techniques practiced in industry?

- RQ4.1 How much specific requirements validation technique is good in terms of catching defects?
- RQ4.2 How much specific requirements validation technique is good in terms of time/schedule?
- RQ4.3 How much specific requirements validation technique is good in terms of cost?

RQ5. What are the differences in the usage of requirements validation techniques practiced in Pakistani and Swedish software industry?

1.4 RESEARCH METHODOLOGY

Qualitative research methodology is used to investigate above mentioned research questions for expected outcomes of this thesis. According to Creswell [15], qualitative research methodology is conducted in natural settings, like visiting participant's office or home for extracting particular information, it enables data collection through open-ended observations, interviews, documents, and all other means of data collection (phone calls, emails, scrapbooks and etc.). Interviews are used as a tool of data collection from people working in the field of requirements engineering in software industry. Along with interviews, rich literature in the form of books, journals and research articles are also be consulted for identifying particular RVTs.

Qualitative research is used in this thesis because it is emergent instead of pre-described [15], a lot of things can emerge during interviews and new questions can be asked according to given scenarios. All the interview questions are focused on requirements validation

techniques. This research method is basically interpretive [15]; we can easily interpret data through particular analysis. For appropriate interpretation of the interviews, some quantitative nature of questions also asked in the interview meetings.

For conducting interviews with Swedish software organizations, face to face meetings are held. While on the other hand, interviews with Pakistani software organization are arranged through telephonic conversation. The analysis of collected data is done in a way that original meaning of research can be properly interpreted. The results obtained after data analysis are helpful in finding the gap between academia and industry.

1.4.1 RESEARCH APPROACH

It is necessary to find out best suitable requirements validation techniques according to given project schedules, cost and resources of every software organization. This research approach is used to explore and identify the requirements validation techniques (RVTs) from academia and industry. There are following steps, which are necessary to pursue for finding out suitable RVTs:

1.4.1.1 PROBLEM ANALYSIS

Requirements validation process is analyzed in the first step of problem analysis, and as a result requirements validation techniques (RVTs) are discussed. Problem analysis that analyzes RVTs, their pros and cons, requirements validation attitudes, and other things are discussed in chapter 5, named as ‘Data Analysis’.

1.4.1.2 LITERATURE SURVEY FOR AVAILABLE RVTs

A short literature survey is presented in chapter 2, which helps to identify requirements validation techniques (RVTs) in academia. These RVTs are discussed under the heading of ‘Requirements Validation Techniques’.

1.4.1.3 INTERVIEW STUDY DESIGN

The process of interview study is discussed in chapter 3, which elaborates that how the activities included in interview process are designed and conducted. Interview study design a series of steps required to be followed for conducting an interview.

1.4.1.4 INTERVIEW RESULTS

The results of interviews are presented in chapter 4, which is named as ‘Interview Results’. The information and data collected from interview results in presented in the form tables and graphs.

1.4.1.5 DATA ANALYSIS

Interview analysis is done in chapter 5, which is named as ‘Data Analysis’. Interview analysis is done after collecting information and data from the interviews. The pros and cons, comparison of different RVTs, and difference in RVTs with respect to Swedish and Pakistani companies are discussed in this chapter.

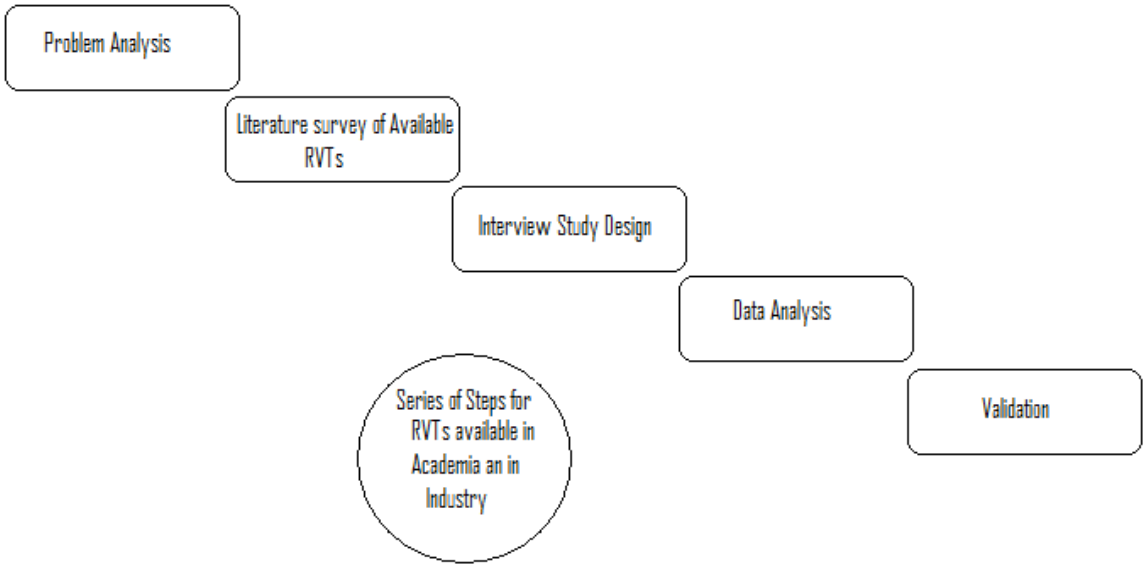


Figure 2 - Series of Steps used in Thesis

2. REQUIREMENTS VALIDATION TECHNIQUES (RVTs)

SUMMARY

Requirements validation is concerned to check the requirements document for consistency, completeness, and accuracy. Requirements validation techniques (RVTs) like: requirements reviews, inspection, reading techniques, prototyping, model-based requirements validation, testing-based requirements validation, and viewpoint-oriented requirements validation are discussed in this chapter. Reviews are one of the most widely used techniques to validate the requirements. Inspection is similar to reviews but not identical, reading techniques define a series of steps to inspect the software artifact. Prototype comes in various forms, from sketches or pictures to the high level fourth generation languages. The main objective of model validation is to show that each and every model is self-consistent, as well as having internal and external consistency. Requirements based testing is a systematic approach for test-case design to consider each requirement and derive a set of tests for it. The objective of viewpoint-oriented requirements validation is to identify and classify problems related to correctness, completeness, and inconsistency.

REQUIREMENTS VALIDATION TECHNIQUES

Requirements are properties or attributes, which demonstrated in a way that how problems of real world can be, solved [3]. They are details of how the system should operate; constraints on the system's operations, and application domain information [1]. According to Kotonya et al. [1], "requirements validation is concerned to check the requirements document for consistency, completeness, and accuracy". Usually, most of the bugs / errors exist in the software are due to incomplete, inaccurate, and inconsistent functional requirements. Figure 3, illustrates requirements validation process; where requirements documents, organizational knowledge and organizational standards are inputs. List of proposed problems and agreed actions for resolving these problems are outputs of the requirements validation process.

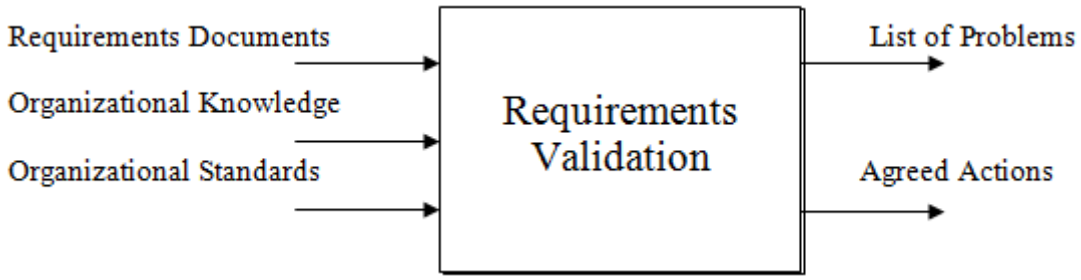


Figure 3 - Requirements Validation Process [1]

There are different kinds of requirements validation techniques available in the literature, some of them are as follows ([1] [2] [7] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38]):

1. Requirements Pre-Reviews
2. Requirements Reviews
   - 2.1 Requirements Inspections
     - 2.1.1 Test-Case Driven Inspection
   - 2.2 Reading Techniques
     - 2.2.1 Ad-hoc based Reading
     - 2.2.2 Check-list based Reading
     - 2.2.3 Perspective based Reading
3. Requirements Prototyping
   - 3.1 Throwaway Prototyping
   - 3.2 Evolutionary Prototyping
4. Model-based requirements validation
   - 4.1 Data-flow Models
   - 4.2 Compositional Models
   - 4.3 Classification Models
   - 4.4 Stimulus Response Models
   - 4.5 Process Models
   - 4.6 Simulation Models
5. Testing-based requirements validation
6. Viewpoint-oriented requirements validation

2.1 REQUIREMENTS PRE-REVIEWS

Pre-reviews are used to save the cost and time from full requirements reviews, whereas full review involves people from different backgrounds and it is better to save time from re-work. The errors which can be easily detected without full review are discovered in the pre-reviews, for instance spelling mistakes, and non-conformance to the organizational

standards, etc [1]. In pre-review one person is dedicated to check the documents for typographical errors, missing requirements and non conformance to the standards. Documents in review are usually sent to the review teams. It will be costly that during review meeting everyone spends time on checking the standards or typographical errors. So, pre-reviews are advisable before going into the reviews meetings of the requirements documents for validation.

2.2 REQUIREMENTS REVIEWS

Requirements review is a technique used to validate the requirements by a group of people. It is a formal process which involves readers from the both sides of clients and developers. Reviews help customers and developers to resolve problems at early stages of SDLC. Time spent during the requirements reviews, pays back by minimizing the changes and alteration in the software. The organizations which have independent review teams usually produce good quality systems [16].

There is no general review process for software development activities. Organizations should design their review processes according to their own needs, customers and market [16]. It is one of the most widely used techniques to validate the requirements. Requirements review process consists of following steps, as shown in Figure 4:

a. Plan review: team is selected, time and place are decided for the review meeting
b. Distribute documents: documents are distributed to the review team members
c. Prepare for review: individuals read the relevant documents for inconsistencies, conflicts, omissions and other problems before review meeting
d. Hold review meeting: individual comments and problems are discussed, set of actions to address the problem is agreed
e. Follow-up actions: checks if the agreed actions are taken place or not
f. Revise document: final document is revised for the acceptance or re-reviews

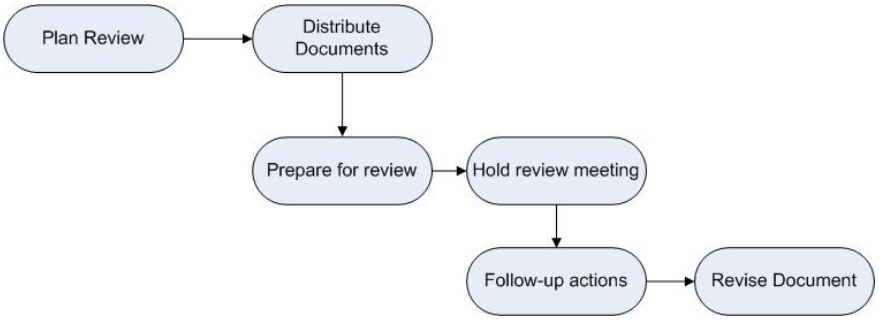


Figure 4 - Requirements Reviews Process [1]

Time required for the review depends upon the size of the document. According to [1], 50 persons hours effort is required from a team of 4 people to inspect requirements document that has 400 requirements. The requirements which are misplaced mistakenly during requirements elicitation should be clarified. If information is missing from the document then it is the responsibility of the requirement engineers to find out from the stakeholders. The requirements which are unrealistic should be deleted or modified for the upcoming development of the system. Conflicts between the requirements should be negotiated with stakeholders to resolve the exposed problems.

According to [17], Review team usually check requirements for completeness and consistency. Review team should point out conflicts, omissions, inconsistencies and errors in the review meetings and should properly note. They may also check requirements for:

a. *Verifiability*: Requirement is testable or not?
b. *Comprehensibility*: Is requirement is understood by the end user.
c. *Traceability*: Is requirement is traceable to the source of origin?
d. *Adaptability*: Is requirement can be changed without large scale effects on the other requirements.

It is very important to invite right people for reviewing the requirements against inconsistency, ambiguity, and other problems. First thing which should be determined is perspective of the requirements in which it is represented, and who can provide those perspectives. According to [18], following stakeholders should be involved in requirements reviews process:

a. *Customers*: are the people who gives input of the requirements or the people who are funding project
b. *Users*: who are directly or indirectly involve with the product
c. *Requirements Analyst*: writes the requirements and communicate with the other stakeholders especially development team.
d. *Developers*: are involved in design, implementation and maintenance of the product
e. *Documentation Writers*: are involved in writing user manuals and training systems
f. *Project manager*: one who plans the project and lead the development team to the successful delivery of the product.
g. *Legal Staff*: are responsible for the product compliance with regulation and all pertinent laws.
h. *Manufacturing people*: build the product that contains software.

2.2.1 REQUIREMENTS INSPECTION

Inspection is similar to reviews but not identical. Fagan [19], introduced inspection in 1970s at IBM, and that is why, sometimes it is known as “Fagan Inspection”. Inspection of software is a very effective way to find the defects of a software product, as it removes the defects at early stages. According to Laitenberger et al. [20], software inspection can detect almost 50% to 90% defects. Inspection is costly and time consuming because of the large number of software artifacts which are required to be analyzed, searched and sorted for this purpose [21]. Requirements inspection is not a common practice in industry due to the cost which is associated to it. The software development of a particular product is less complex in early stages as compared to the later ones of the SDLC, and it saves a lot of re-work if we precisely and correctly inspect the requirements as early as possible [21]. Inspections are mostly used by the people who actually study state-of-the-art, and select best practices. Inspection process consists of following six steps, which are:

a. Planning: organize meetings when all the documents are available
b. Overview: make the product understandable to the viewers
c. Defect detection: identify the defects in software artifacts
d. Defect collection: defects are collected and documented, decisions are taken on those defects and decide to re-inspect the software or not
e. Defect correction: defects are corrected on the basis of feedback
f. Follow-up: all the reported defects are removed from the software artifacts

Roles and responsibilities in requirements inspection are expressed as following:

a. Moderator: is responsible for the selection of team and he/she ensures that team will perform its duties according to each and every phase. Moderator is the key person in the inspection process.
b. Inspector: is responsible for finding the defects.
c. Organizer: plans all the activities within or outside the project.
d. Producer: is a person, who has developed software artifacts, s/he is responsible to explain the software artifacts to all team members.
e. Recorder: is responsible to note-down all the defects in the defects list during inspection meeting. It is an optional position.
f. Reader: is responsible for presenting all the material. He/she should explain and interpret all the material.

2.2.1.1 Test-Case Driven Inspection

Test-Case Driven (TCD) inspection technique was proposed by Gorschek et al. [22]. This technique is used to remove the defects before project started (known as pre-project phase) and during the project. The purpose of this technique is to ensure that requirements are good enough for the product and planning activities. The aim of this validation technique is to minimize the cost, and effective requirements inspection [23]. TCD inspection is used in market driven environment where we have large number of requirements. The requirements are inspected for the good-enough for the decision support material for the requirements triage and selection [22].

TCD inspection is beneficial for the minimization of resources and the reuse of software artifacts and personnel. TCD inspection of requirements consists of three steps, which are performed in pre-project phase. TCD inspection steps are:

a. Step 1: product manager selects and reviews the requirements to be included in the initial specification and some requirements are also discarded. This is mostly ad-hoc process, the selected requirements known as formulated or specified requirements.

b. Step 2: Usually two persons are involved in TCD inspection, which are project manager and tester. These two people are already trained and have expertise in their field; it will minimize the cost which was supposed to spend on the training of the personnel. Inspection of the requirements is performed in this step to create test-cases for the requirements. The requirements which have lower priority should be removed in this step.

c. Step 3: Project planning and requirements prioritization is done in this step. Requirements that are not required, discarded in this step.

After test case driven inspection, requirements are selected for implementation.

2.2.2 READING TECHNIQUES

Reading techniques define a series of steps to review/inspect the software artifact. In reading techniques, specific methods are given to the reviewers that how to read and what to look in software artifact. There are several reading techniques are available in the literature, for example: ad-hoc based, checklist based, perspective based, and defect based readings. Ad-hoc based and checklist based readings are the most popular in the industry for defect detection [24].

2.2.2.1 Ad-Hoc Based Reading Technique

Ad-hoc based reading provides very little reading supports. In this reading technique artifacts are given to the reviewers/inspectors for review/inspection without any guidelines. The defect detection is depending upon the knowledge and experience of reviewer/inspector [25].

2.2.2.2 Check-List based Reading Technique

Checklist based is one of the commonly used techniques. According to [26], check-list based reading technique is used to be a standard reading technique in most of the organizations. It contains set of questions which guides the reviewer/inspector during review/inspection. Check list based reading technique includes questions which are related to quality of the requirements [25].

Checklist Questions	Quality Attribute
Is each requirements is easily Identified?	Traceability, conformance to the standard
Are specified terms are defined in the glossary	Understandability
Do individual requirements use the same term in different ways?	Ambiguity
If a requirement makes references to some other facilities; are these described elsewhere in the document?	Completeness
Are related requirements group together?	Organization
Are there any contradictions in the requirement?	Redundancy
Do you have to examine other requirements to understand what it means?	Completeness

Table 1 - Check-List Questions [1]

Some of the examples of checklist based questions can be seen form Table 1, which are given by Kotonya et al. [1]. According to Laitenberger et al. [27], the survey of weaknesses of the check list based reading techniques are:

a. Check list questions are more general
b. Instruction for how to use checklist are often missing
c. Questions are designed according to defects that previously detected and belong to particular defect type.

2.2.2.3 Perspective based Reading Technique

In perspective based reading, reviewers are assigned a specific perspective, when they review/inspect a software artifact. When a reviewer has specific perspective then it is more helpful to detect specific types of faults. In this technique reviewer is more focused because he/she try to find specific type of fault whereas in other technique they are responsible to detect all types of faults. There is another advantage of perspective based reading is that they work in a more structured manner and read it actively [28].

Perspective based reading represents customer, tester and the designer. From these three different perspectives, reviewers/inspectors are advised to use a scenario based reading approach to read the requirements [29]. While answering the questions the inspectors take notes of potential defects discovered that would affect the stake-holder's responsibilities [30]. The main reason behind perspective based reading is that if several readers inspect the documents from different stake-holder's perspectives then this will result in a document which represents actual requirements.

2.3 REQUIREMENTS PROTOTYPING

Prototyping is mostly used to give an overview of the requirements being imposed or implemented in the proposed system. It is very difficult for the user to understand that how the written requirements will be transformed into the executable form of system [1]. According to Sommerville [17], the main purpose of requirements prototyping is to understand the requirements of the system and it is mostly used for:

a. *Requirements Elicitation*: in this phase, prototyping helps users to understand how the system will support their work.

b. *Requirements validation*: in this phase, prototyping helps to identify the errors, and omissions of those errors from requirements document.

Prototype comes in various forms, from sketches or pictures to the high level fourth generation languages. Mostly organizations create multiple prototypes, for example: first they create sketches on paper or on white board and then they develop operational prototype using high level language. According to Davis [31], there are two types of prototyping, as shown in Figure 5, which are *throw-away* and *evolutionary prototyping*:

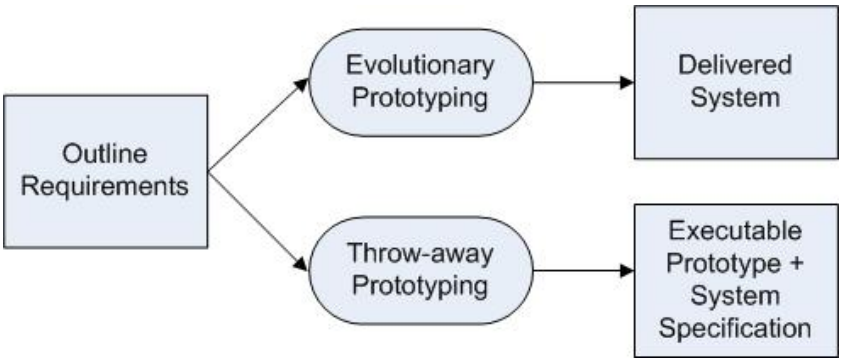


Figure 5 - Approaches to Prototyping [17]

2.3.1 Throw-Away Prototyping

Throw-away is a type of prototyping, in which limited functionality is available and it used to develop poorly understood requirements before starting the actual development [31]. According to Sommerville [17], the purpose of throw-away prototype is to clarify the requirements and to assess the potential process risks. It should not be considered as a final system. It is developed from initial phase to experiment phase and then it is discarded. In throw-away prototyping, we develop requirements which are difficult to understand for the customers. The requirements, which are clear, should not be developed through this prototype. If both the customer and the developer are agreed upon the requirements, then prototype should be discarded [32].

2.3.2 Evolutionary Prototyping

Evolutionary is a type of prototyping in which we develop the requirements that can be easy to understand by the customers and have high priority. The objective of evolutionary prototyping is to deliver a workable system to the end user, and it should exhibits all the quality attributes of the final product [31]. It is best suited when developers have minimum contact with the stakeholders. There are some quality factors which usually affect the evolutionary prototyping, like performance, design quality, and maintainability. These attributes will suffer if steps are not properly followed [33]. Evolutionary prototype must be

used when we cannot develop specification in advanced for e.g. user interface system and AI (artificial intelligence) system [17]. Some of the difference between throw-away and evolutionary prototyping are give in Table 2.

	Throw-away	Evolutionary
Development Approach	Quick	Precisely developed (takes time)
What to build first	Difficult parts	Build understood part first
Goal	Throw it away	Evolve it

Table 2 - Comparison of Prototyping Types [31]

2.4 MODEL-BASED REQUIREMENTS VALIDATION

The formulating, structuring, and modelling requirements can be guided by a requirements method. It is a systematic approach for documenting, analyzing, and validating the system requirements. Furthermore, a notation that gives means of expressing requirements is also associated with the method [1]. There is no single ideal requirement method available but a variety of modelling techniques are used to formulate the system requirements. According to Kotonya et al. [1], several modelling techniques are used for the validation of the requirements, some of them are:

2.4.1 Data-Flow Modeling

Data-flow approaches are using data-flow diagrams (DFD) to graphically demonstrate that how data is processed at different stages of the system. As it can be seen from Figure 6, DFDs represent external entities, processes, data-flows, and data stores.

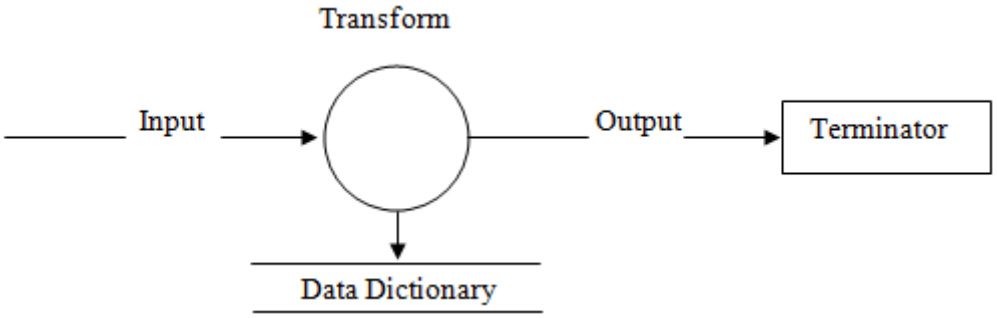


Figure 6- Data-Flow Diagram Notation [1]

According to Maciaszek et al. [34], the backbone of DFDs is functional decomposition, as it can be seen from following Figure 7. Functional decomposition is a top-down activity, which is started from a context diagram and finished at module specification.

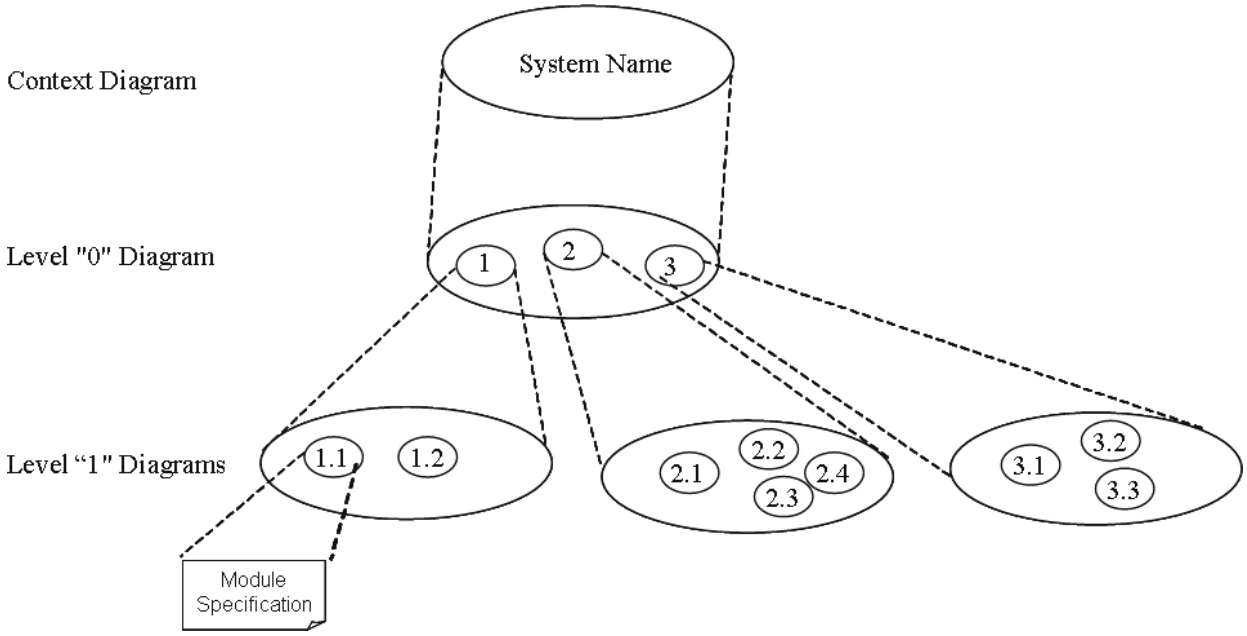


Figure 7 - Functional Decomposition in DFD [34]

2.4.2 Compositional Models

Entity-relationship diagram (ERD) can be used to illustrate how entities are composed of other entities as shown in Figure 8. An ERD mostly consists of four different graphical components, which are: entity, relationship, cardinality, and attributes. The most popular variant of this technique is known as "crow's foot notation" [34].

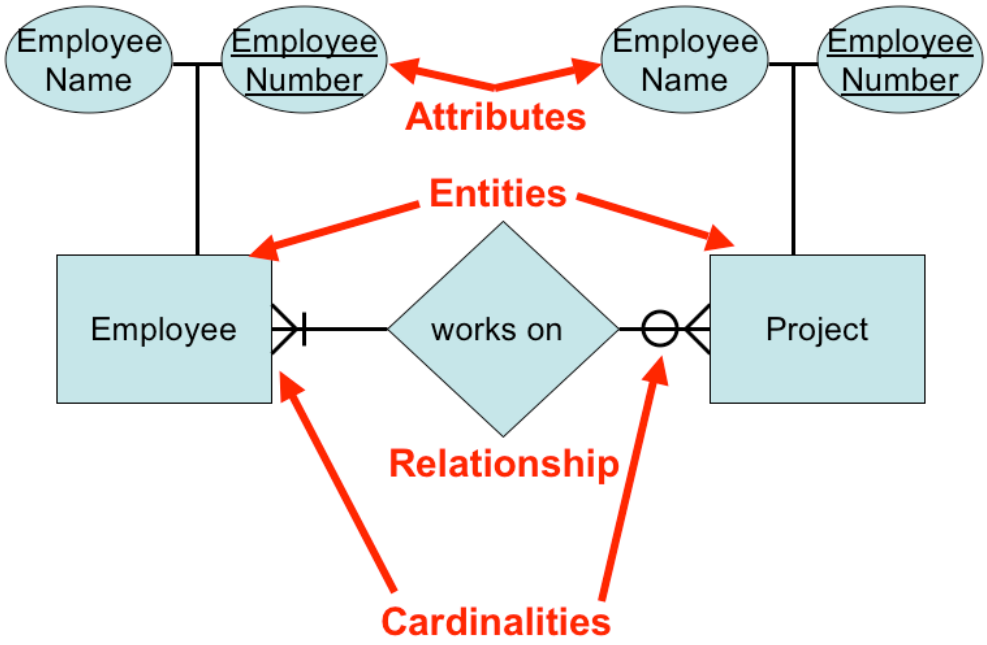


Figure 8 - Entity Relationship Diagram (Simple Example) [35]

2.4.3 Classification Models

Object / inheritance diagrams can be used to demonstrate how entities have common attributes, as shown in Figure 2.7 and Figure 2.8. According to Kotonya et al. [1], object-oriented modelling includes following fundamentals concepts: *object and classes*, *methods*, *messages*, *encapsulation*, and *inheritance*.

i. **Object** can be defined as anything real or abstract about to which we store data and operations on that data to manipulate it. Every object has a list of *attributes*; which portrays some aspects of the object that belongs to it.

ii. A **class** is an implementation of objects that refers to objects, which share common attributes and operations. Object is mostly known as an instance of a class.

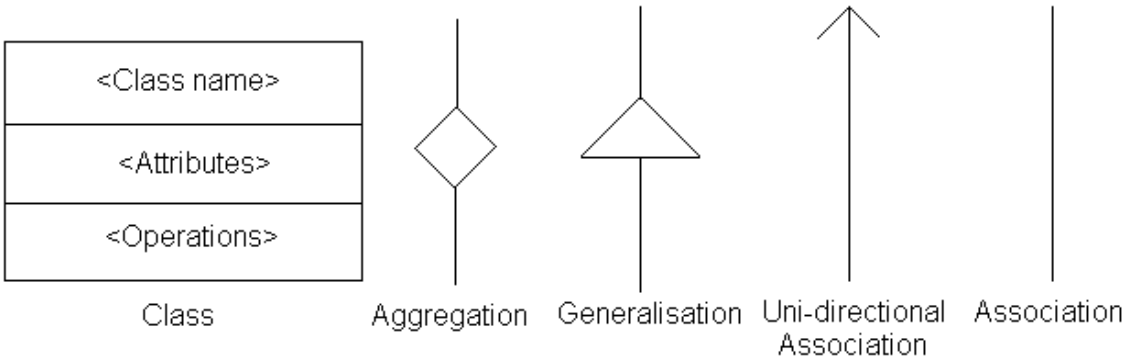


Figure 9 - Object Notation [1, 34]

iii. Each and every object has an associated set of **methods** (operations and procedures) that might be known as object from outside and which can act on object's attributes.

iv. **Encapsulation** is known as the packaging together of data and operations that manipulate the data. User does not know the details that how the operation is performed but instead it can understand which operation may be requested through an object.

v. **Inheritance** decompose the classes into objects, objects at the lower level in the hierarchy by definition inherit the operations and attributes of their parent(s). When an object inherits data from more than one parent, it is known as multiple-inheritance.

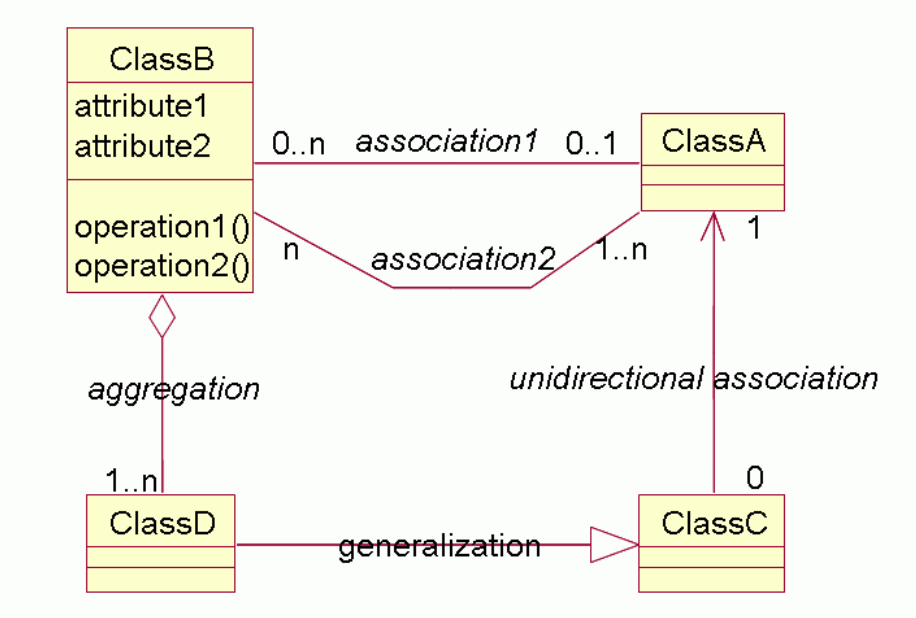


Figure 10 - Modeling Elements of Class Diagram [34]

2.4.4 Stimulus Response Models

State transition diagrams can be used to demonstrate how the system reacts to internal and external events

2.4.5 Process Models

Process Models are principal activities and deliverables that are involved in carrying out some processes.

2.4.6 Simulation Models

According to Maria [36], the simulation models are described as following:

1. Demonstration of developing and working of some system of interest is known as model. The operation of a model of the system is known as simulation.

2. Performance of an existing or proposed system can be evaluated by using simulation, under different configurations of interest and over long period of time.

3. Simulation can be used to reduce the chances of failure to meet requirement specifications, before alteration of an existing system or developing new system, to eradicate unforeseen bottlenecks, to get exact utilization of resources and optimization of the system performance.

The main objective of model validation is to show that how each and every model is self-consistent, as well as having internal and external consistency. Model validation precisely reflects the system stake-holder's requirements. The involvement of stakeholders in the model validation process is very important. It is difficult for non-technical people to understand for instance data-flow diagrams, event-diagrams, or object models. Therefore it is suggested to work with natural language descriptions even when models say precisely the same thing with the help of diagrams [1]. In this way it will be easy to detect errors, inconsistencies, and incompleteness in the models. The models have much more complete semantics and it is easy to prove their consistency mathematically.

2.5 TESTING-BASED REQUIREMENTS VALIDATION

According to Liu et al. [37], the requirements testing mainly involve requirements integrity, consistency, data's sharp definition, requirement ambiguity, and testability of the requirement. Requirements based testing is a systematic approach for test-case design to consider each requirement and derive a set of tests for it. Testing of the requirement means that it can define one or more tests which may be carried out when the system will be developed. This requirements validation practice will evidently portray that the newly developed system is according to its requirements [1]. It is always desirable that all the requirements should be testable.

Actual testing is executed after the development of the system. It is an effective way of exposing requirements problems like incompleteness, inconsistency and ambiguity through suggesting possible tests of the requirements [1]. If it is difficult to derive test-cases for a specific requirement of the system then it means that there is some sort of problem with the requirement [1, 37]. This could be missing of information in the requirement or its description may not give a clear picture. So each of the functional requirements in the requirements specification document should be thoroughly analyzed, and define tests for it to check objectively if the system satisfies its requirements or not.

According to Sommerville [17], requirement should be written in such a way that designing of test-cases for each of the requirement should be easy. So, as a result developers can check requirement is implementable or not. The purpose of suggesting test-cases for requirements is to validate the requirements instead of validating the system. While defining the test-cases for the requirements, some important considerations should be kept in mind [1], which are:

i. The usage scenario of the requirements defines context in which the test should be applied.

ii. It is necessary to make sure that the requirement, on its own, contains enough information for test-case to be defined.

- If information is not available in that specific requirement then other related requirements should be looked at to get this information.
- In case of getting information from other requirements, the requirement for which information is searched should be recorded.
- These requirements might be dependent on each other, so it is necessary to record them.

iii. Always check that requirement is using single or multiple test-cases. Along with this, it is also possible that there might be more than one requirement described in a single requirement description.

iv. Test-cases should be obvious if the requirement re-stated.

Kotonya at al. [1] suggested that a test record form for each and every requirement, which is tested, should be designed and filled in with following information:

The Requirement's Identifier

a. *Related Requirements*
b. *Test Description*
c. *Requirements Problems*
d. *Comments and Recommendations*

2.6 VIEWPOINT-ORIENTED REQUIREMENTS VALIDATION

Viewpoint-oriented requirements definition (VORD) is a method, which basically planned for identifying and specifying the interactive systems (based on viewpoints that focuses on user issues and organizational concerns), but it is also possible to use it for specifying other classes of system [1]. According to Sommerville et al. [38], viewpoint based approach for requirements engineering identifies that a single perspective of the system requirements cannot discover all of its related information. There should be different number of viewpoints, which are considered to collect and organize all the requirements. Leite et al. [2] suggested this approach, which is based on viewpoints that can be used for early requirements validation.

The objective of viewpoint-oriented requirements validation is to identify and classify problems related to correctness, completeness, and inconsistency [1, 2]. An encapsulation of partial information about a system's requirements can be called as a viewpoint [38]. The process of viewpoint resolution is concerned with identifying differences between two different viewpoints, classifying and evaluating those discrepancies, and integrating different solutions into a single representation [2].

An explicit statement of the perspective adopted by a viewpoint is known as that viewpoint's focus [39]. Figure 11, illustrates an example of different overlapping viewpoints, which is important to discover potential requirements conflicts. According to Leite et al. [2], this approach contains certain concepts which are necessary to understand for view-point oriented requirements validation. These concepts are:

a. The **Universe of Discourse** is overall context for developing the software. Along with this, it contains all sources of information including all the people associated to the software.

b. People are known as **actors** in the universe of discourse.

c. A **viewpoint** is known as a standing or mental position of an individual while examining or observing the universe of discourse.

d. "A **perspective** is a set of facts observed and modelled according to a particular modelling aspect and a viewpoint"

e. The relationship between entities and attributes is known as **fact**.

f. A **view** is an integration of perspectives and hierarchies.

g. There are two types of **hierarchy** concepts which are used, known as 'is-a' and 'part-of' hierarchies in the universe of discourse.

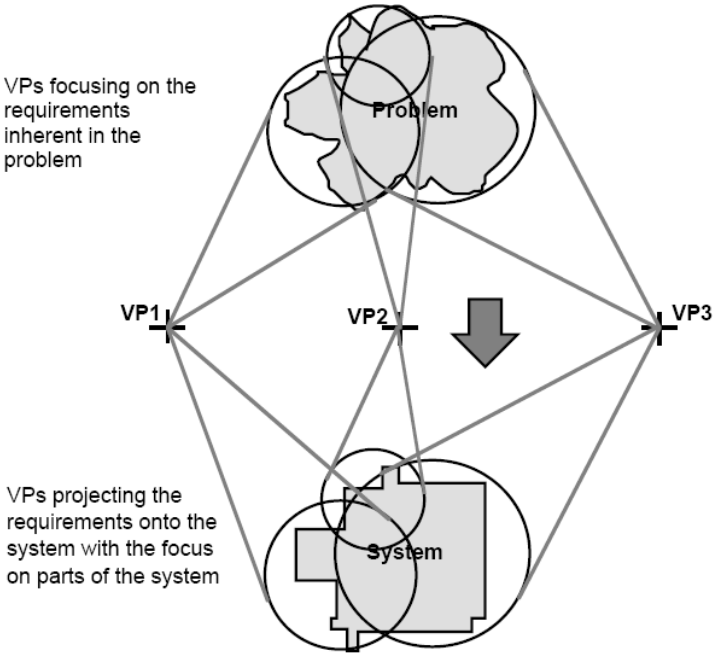


Figure 11 - Viewpoints on a Problem [38]

Three perspectives (data, actor, and process perspectives) and two hierarchies (is-a, part-of) are used to construct a view, where a system analyst explains the problem. After the comparison of perspectives and hierarchies, a list of discrepancies and types of discrepancies are created. When a chain of analysis is available, each and every analyst resolves the internal conflicts and integrates their final perception into a view, which describes perspective and hierarchies together [2]. Views are taken from the viewpoints, which are required to identify and classify the discrepancies between different viewpoints for correctness and completeness.

3. INTERVIEW STUDY - DESIGN

Summary

Interviews are conducted as data collection instruments for getting information related to requirements validation techniques (RVTs) from software industry. Interviews are selected in place of survey because we can get in-depth information regarding any particular questions during the interview. The interview design study consists of followings elements: Interview structure; interviews may result in insufficiently, irrelevant and/or worthless information. Semi-structured interviews are comparatively informal and comfortable discussions, which are based on a pre-arranged topic. There are three particular selection criteria for the interview subjects (interviewees). An interview questionnaire is designed to conduct the interviews. The interview operation including preparation, execution, and data validation are discussed in this chapter as well. Along with this, relationship between research questions and interview questionnaire is also part of the chapter, in which a mapping between the questions is discussed.

INTERVIEW STUDY DESIGN

Qualitative research approach is used to find out appropriate requirements validation techniques (RVTs) available in academia and also practiced in industry. Ethnographic strategy will be conducted to inquire information related to RVTs practiced in industry. Interviews as data collection instrument are used to get required information [15]. Interviews are selected in place of survey because we can get in-depth information regarding any particular questions during the interview.

According to Creswell [15], interview as a data collection instrument gives options to conduct face-to-face, one-on-one, in-person interview or conduct interview through telephone. An interview design study consists of followings:

3.1 INTERVIEW STRUCTURE

It is usually considered that interview is an easy way to get required information from the interviewee. However, interviews are problematic and time consuming for extracting exact required information [39, 40]. Interviews may result in insufficient, irrelevant and/or worthless information. Actually, it is essence of the interview to ask every question on its rightful place while conducting an interview. So, the important thing is to structure the interview in an appropriate manner for eliciting required information from the subject. Authors have decided to construct a semi-structured interview for exploring information about requirements validation techniques used in different organizations.

3.2 SEMI-STRUCTURED INTERVIEW

A semi-structured interview is comparatively an informal and comfortable discussion that is based on a pre-arranged topic [41]. Here, the purpose is to acquire information from individuals' (e.g. Project Managers) who are working in software industry on requirements validation techniques. In semi-structured interviews such questions are asked which do not limit the discussion, and new questions are acceptable as a result of conversation [41].

Semi-structured interview technique is used for the collection of information about RVTs from different software organizations. The reason for choosing this interview technique is simple. It uses open-ended questions; most of the questions in this technique arise naturally during the interview. If any question appears in mind, during the interview can be asked at the same time. As authors are two group members, one person asks questions during the interview and other person note down the details. During the interview, if any question left un-investigated by one person can be asked by other respondent at the end of the interview.

A set of open-ended questions is prepared before the interview, for permitting interviewee to convey his / her views throughout the conversation. While preparation, authors keep questions simple and create a logical sequence in between them for controlling the flow of

information. The interview is qualitative in nature but authors also have to take out quantitative data from it as well. The interview is started from most general questions and then in-depth technical details related to RVT. The benefit of semi-structured interview is that the complex questions can be easily clarified during the interview, and authors can go into further depth.

3.3 SELECTION OF INTERVIEW SUBJECTS

This study report is based on the information acquired from academia and practiced in software industry. The interviews are conducted with software related personnel working in software engineering domain, especially in requirements engineering. There are three particular selection criteria for an interview subjects (interviewees), which are:

1. Subject should be involved in software development, especially in software requirements validation.

2. Subject should be in a senior position e.g. as project manager, software engineer or quality assurance manager and have at least 3 years of experience.

3. The designation/role of the subject should be equivalent as described in criteria number 2, in all the selected companies.

3.4 INTERVIEW QUESTIONS

Authors designed the research questions with the help of a short literature survey, and from past industrial interview experiences. While striving for research questions, authors came to know that most of the interviews are done on requirements engineering rather than requirements validation. For creating interview questions, related to requirements validation techniques, authors started from brainstorming, identified possible areas of RVTs, which are relevant to the described research questions. After that authors write down possible RVT related questions for interview; these questions are constructed with the help of literature. In group meetings, authors discussed each and every question on the whiteboard, and possible redundant questions are removed. After comments and feedback from supervisor of this study, one interview questionnaire is evolved.

According to the suggestions of supervisor, authors performed dummy interviews, where one of the group members acted as an interviewee and the other as interviewer. This activity repeated again but with opposite roles. As a result of these interview practices, some questions are removed from the questionnaire, which were not relevant to the domain. Along with this, few questions added/ updated, which are considered necessary for the interview. Time factor is considered important here, so authors practiced this activity again and again, and tried to complete the interviews in 45 – 60 minutes.

After this exercise of interviews; a questionnaire was improved but still it required time to be finalized. Authors involved some of their friends in this interview process who were familiar with requirements engineering, especially with RVTs. Authors collected quantitative and qualitative data from the interviews. At this stage answers are coded in Microsoft excel sheets; tables and graphs are drawn from collected data. The questions which did not map to the research questions were excluded. This process was repeated until all interview questions were mapped to the research questions. Different interview questions were related for drawing new findings in terms of interesting results. Finally, authors gave interview questionnaire (APPENDIX 1) to the supervisor for final approval.

3.5 OPERATIONS

After creating interview questionnaire, authors have started to contact persons in different software companies of Pakistan and Sweden for interviews. The following sections contain information that how the interview process is pursued. Also preparation of the execution of the interviews and validation of the data is explained in following sections.

3.5.1 Preparation

Authors started correspondence with particular personnel (like, project managers and quality assurance managers) through emails and telephone, which are working in different software companies, for the purpose of conducting interviews. During this communication (through emails and telephone) with the subjects, authors gave them an overall idea that what the interview is all about. Along with this, authors gave them an overview about different terminologies and definitions, which are part of the questionnaire. In-fact, software industry is practicing most of these techniques and activities, but they hardly know the actual names of these terminologies. Authors conduct interview in two ways:

1. Interviews with Swedish software organizations are conducted through face to face meetings.

2. Interviews with Pakistani software companies are conducted through telephonic conversation.

3.5.2 Execution

Before conducting the actual interview, authors have discussed each and every question that is given in the questionnaire, for the purpose of preparation and clarification, before the actual interview meetings. While conducting interviews from different software companies, authors did not interfere in the discussion of the interviewee unless he/she deviate from asked questions. Authors conducted interviews in such a fashion that one of authors' member is dedicated to take notes, just for making sure that no information is going to be lost. Authors did not record the interview, just to make sure that interviewee does not hesitate to give required information. Authors have already set time for the interview meetings with the interviewees that is approximately 45 – 60 minutes.

3.5.3 Data Validation

After conducting the interview in case of any confusion, answers are verified from the interviewee. This helped authors to understand and verify the answers. If still ambiguities left in the gathered information, then this is cleared through asking by the email or telephone. The aim is to identify the requirements validation practices used in different software companies of Pakistan and Sweden. Data was collected from multiple people of six companies; interviewee is not sure about the exact answers, so authors conduct multiple interviews to know the exact answers.

3.6 RELATIONSHIP BETWEEN RESEARCH QUESTIONS AND QUESTIONNAIRE

> RQ1- What are the requirements validation techniques available in the literature?

Authors have done a short literature survey to identify requirements validation techniques available in academia, and can be used in software industry. So, this research question is not directly considered for the interview questionnaire but requirements validation techniques are described in chapter 2.

> RQ2- What are the requirements validation techniques used in different organizations in Sweden and Pakistan?

This research question is directly asking about the RVTs used in software industry. There are several requirements validation techniques, proposed in literature but not practiced in industry. So, authors have developed an interview question for that is directly linked to this research question. For example:

Which requirements validation techniques do you use for your projects?

> RQ3- What are the pros and cons of requirements validation techniques used in software industry?

This research question is discussing about pros and cons of the RVTs, which means that each and every RVT has some advantages and disadvantages associated to it. This means that if any software organization is using some particular RVT, then its benefits and limitations are attached to that particular organization. In order to find the pros and cons of requirements validation techniques, authors have directly developed a question, which cares this research question. Authors have asked pros and cons of each of the requirements validation techniques, which are used in software industry. This research question is directly mapped to our interview questionnaire, for example:

Can you give two pros and two cons of requirements reviews?

> RQ4. What is the comparison of different requirements validation techniques practiced in industry?
>
> | | |
> |---|---|
> | RQ4.1 | How much specific requirements validation technique is good in terms of catching defects? |
> | RQ4.2 | How much specific requirements validation technique is good in terms of time/schedule? |
> | RQ4.3 | How much specific requirements validation technique is good in terms of cost? |

This research question is mapped to the interview questionnaire as well. Interview questionnaire contains both quantitative and qualitative type of questions for extracting required information. The collected information is helpful for comparing all the requirements

validation techniques, which are used in industry. The examples of some questions from the questionnaire are following, which can be directly mapped to this research question:

Are you satisfied from requirements review as validation technique in terms of?

1. Catching Defects Bad ----1|----2|----3|----4| Very Good
2. Time / Schedule Bad ----1|----2|----3|----4| Very Good
3. Cost Highest ----1|----2|----3|----4| Lowest

Do you think that there is any room for improvement in requirements review practice? If yes then what?

How much time requirements reviews take in accordance with total requirements validation time?

What are reasons behind selecting these requirements validation techniques?

a. *These are your favorite techniques*
b. *These are the only techniques you know*
c. *These techniques are more suitable in your particular scenario*
d. *Other …*

RQ5. What are the differences in requirements validation techniques practiced in Pakistani and Swedish software industry?

After conducting interviews, authors have analyze the outcomes and extract differences of RVTs used in both the countries that how they differ in their usage. This analysis is done in chapter 5, for example: some of the companies have development efforts distributed over different sites. Authors identify that how the companies validate their requirements through different validation techniques. Along with this, authors have analyzed the perceived problems and shortcomings of the requirements validation techniques.

4. INTERVIEW RESULTS

Summary

The data of interview results is presented in the form of tables and graphs, which are related to the requirements validation techniques (RVTs) practiced in software industry. The study of six companies is presented in this chapter; their respective names are company X, Y, Z, A, B and C. Reviews and prototyping are practiced as RVTs in all the six companies, which we have interviewed. Testing-based RVTs are practiced in three companies, while model-based RVTs are used in two out of six companies. Pros and cons of each of the RVTs are presented in the form of tables. Satisfactory level in terms of catching defects, time/schedule and cost are also available in the form of quantitative data. Along with this, improvements suggested by different organizations are presented for each of the RVTs as well.

INTERVIEW RESULTS

In this section, authors have presented pedagogical text that is results of the interviews, conducted in different software organizations. The data of interview results is presented in the form of tables, which is related to the requirements validation techniques (RVTs) practiced in software industry. All the interviews are conducted in such a manner that both the authors were present there, just to make sure that RVTs related information is extracted and noted properly. The information regarding software organizations, in which authors have conducted interviews, is present in following section 4.1 that gives a brief introduction about the companies.

4.1 INTRODUCTION TO THE COMPANIES

This thesis report comprises the study of six companies in two countries (Pakistan and Sweden); three companies from each of the countries. It seems beneficial for the readers to know upcoming interview analysis along with understanding the context in which authors are going to analyze the information regarding requirements validation techniques of the companies. Due to confidentiality issue, authors do not want to disclose the names of the companies. The information of brief introduction is taken from the websites of the companies and their interviewees. Authors are going to refer the names of the companies as following:

4.1.1 COMPANY A

This company provides services of geo technology and information technology to businesses and governments. They are working on bespoke along with market driven project. They are providing expertise as workflow solutions enabling their professionals to develop customized business software applications for the rapidly evolving global business requirements. They also design and develop modules, application and utilities for many companies and organizations worldwide. Along with this, it is a CMMI level-3 certified company.

Interviewee ‘A’ is working as a ‘Quality Assurance Manager’ for four years but his overall experience spans the duration of seven years. He is also involved in validating the requirements of the software projects. The interviewee was selected for conducting the interview through proper process (as described in section 3.3).

4.1.2 COMPANY B

This is an IT solution provider with specific focused areas in technology spanning business solutions enterprise development, enterprise services and learning solutions. They are working on both bespoke and market driven projects. They have different types of customers. It is CMMI level 3 certified company, they are also doing offshore and onsite projects.

The interview subject ‘B’ is working as a ‘Project Manager’ and has overall more than six years industrial experience, and his specialty is in product development and R & D. Interviewee ‘B’ is also directly involved in the process of validation requirement. The interviewee is fulfilling the selection criteria (as in section 3.3) that authors have introduced for conducting interview.

4.1.3 COMPANY C

This company develops business automation type of applications for the clients in USA. It is mostly doing offshore development. It delivers custom applications, programming services to end customers and IT companies. They are developing bespoke projects. Most of the clients are unaware of their requirements and they do not have too much knowledge.

Interviewee 'C' is working as a 'senior Software Architect' at software company C. He is working in software industry since 2004. Along with other participation, interviewee 'C' is involved in the process of validating the requirements. Interviewee 'C' is also fulfilling the selection criteria (as in section 3.3) for conducting interviews for identifying RVTs used in industry.

4.1.4 COMPANY X

This company is a world-leading provider of telecommunications equipment and related services to mobile and fixed network operators globally. They are one of the few companies worldwide that can offer end to end solutions for all major mobile communication standards. This company is expert in their domain and they know what they want; the customer of this company has extensive system knowledge. This company keeps huge share of the market.

Interview Subject 'X' is working as a 'Project Manager' and have more than 10 years of experience. The interviewee 'X' is directly involved in requirements validation process. The interviewee was selected (as per described in section 3.3) for conducting the interview regarding requirements validation techniques used in Company X.

4.1.5 COMPANY Y

This Company creates and licenses the open software platform to leading mobile phone manufactures. Their flexible and customizable interface and development platform is pre-integrated and tested with Symbian OS, the leading industry standard operating systems for the smart phones. Their open software platform is used in mobile phones from Sony Ericsson, Motorola, BenQ and Arima. The customers of this company have extensive knowledge of the system.

Interview subject 'Y' is currently working as a 'Supplier Manager', he was also working in the same company as a 'Project Manager'. Interviewee Y has overall more than seven years experience. The interviewee Y is also fulfilling the selection criteria (in section 3.3) for conducting the interview.

4.1.6 COMPANY Z

This company is currently one of the leading mobile phone manufacturers in the world. It is an important industry player operating in the 80 countries of the world. Their R & D sites are in Europe, Japan, China, India and North America. They have good knowledge of their system and they know that they want.

In company 'Z', authors have conducted more than one interviews at different positions for extracting required information related to RVTs. Interviewees 'alpha' and 'beta' were involved in the interviews. Both the interview subjects are working in the requirements domain; interviewee 'alpha' is head of the requirements department, while interviewee 'beta' is working as an 'engineer' in technical working group in requirements domain of the organization. Interviewee 'alpha' has working experience of more than ten years and interview subject 'beta' has more than three years working experience in this domain.

4.2 RVTs USED IN INDUSTRY

Requirements validation techniques (RVTs) practiced in software industry are presented in table 3. This table illustrates in such a way that all the companies and their respective countries are written in the columns and the RVTs used in those particular companies are written in rows of the table.

Country	**Sweden**			**Pakistan**		
Companies RVTs…	Company X	Company Y	Company Z	Company A	Company B	Company C
Reviews	*	*	*	*	*	*
Prototyping	*	*	*	*	*	*
Testing Based RVTs		*			*	*
Model Based RVTs	*					*

Table 3 - RVTs used in Swedish & Pakistani Companies

Table 3, illustrates six companies and their respective names as company X, Y, Z, A, B and C. All six companies are using reviews and prototyping as their requirements validation techniques (RVTs). Testing based RVT is used in company Y, B, and C, model based RVT is used in companies C and X for validating the requirements of their particular projects.

4.3 REVIEWS AS RVTs

Reviews are practiced as requirements validation techniques in all the six companies, in which we have conducted interviews. The information related to reviews as RVTs is given as following:

4.3.1 PERSONNEL INVOLVED IN REVIEWS

Companies	**Personnel Involved in Review Activities**
Company X	System Manager, Design Coordinator (Representative of defected designs), Quality Assurance Person, and System Expert.
Company Y	Project Manager, Technical Architect, Software Engineer, and Quality Assurance Person
Company Z	Software Architect, Requirements coordinator, developers, System Engineer, Functional Group leader, and Quality Assurance Person
Company A	Customer, Quality Assurance person, Developer, and Project Manager
Company B	Project Manager, team leader, and Customer
Company C	Project Manager, Senior Architect and Team Lead

Table 4 - Personnel Involved in Review Activities

The personnel involved in reviews in different organizations can be seen from table 4. System manager, design coordinator (representative of defected designs), quality assurance person, and system expert are involved in validating the requirements through review process in company X. Company Y involves project manager, technical architect, software engineer and quality assurance person in their review process for validating requirements of their projects. The review process of company Z involves software architect, requirements coordinator, developers, system engineer, functional group leader, and quality assurance.

Project manager, quality assurance person, developer, and customer are involved in validating the requirements of their projects in company A. Company B involves project manager, team leader and customer in their review process for validating the requirements of their projects. Project manager, senior architect and team lead are involved in validating their requirements through review process in company C.

4.3.2 PROS & CONS OF REVIEWS

Review process as RVT practiced in all the six companies; it has some specific pros and cons, which are shown in table 5. The pros of reviews as RVT in company X are described as; it helps in removing defects and ambiguity from requirements of the projects. The cons of reviews in company X are described as; proper time is required for preparation of the review meetings and proper resources are not available. The pros of reviews as RVT in company Y are: it is easy to remove defects and reviews are educational as well. While the cons of reviews in company Y are resource unavailability and risks attached to reviews.

Companies	Pros of Reviews as RVTs	Cons of Reviews as RVTs
Company X	Reviews helps to Remove Defects, and also Remove Ambiguity in the requirements	Time Required for preparation, requirements written only in text without diagrams/maps is negative, resource unavailability
Company Y	Easy to Remove defects, Educational	Resource unavailability (Time to time put overload and strain), Risks with Reviews,
Company Z	Consistency, Better Quality Estimates, Detailed Time Schedule , requirements clarity people from different backgrounds together, give clear view of the requirements and have different perspective	Time Consuming, resource unavailability, checklist, Too much required for preparation and lengthy process. difficult to prioritize the exact activities
Company A	Removes assumptions , and Reduce Rework	Time Consuming, lengthy process, resources unavailability
Company B	Completeness, and Reduce Rework,	Lengthy process and time consuming, client do not take ownership. Too much documentation kills the effectiveness of reviews.
Company C	Real Requirements from customers, resolve conflicts and removes assumptions	Time Consuming, Resource usage

Table 5 - Pros and Cons of Reviews as RVTs

The pros of reviews in company Z are: consistency, better quality estimates, detailed time and schedules, requirements clarity due to the people involved in review process, having different backgrounds and different perspectives, and it gives clear view of the requirements. The cons of reviews process in company Z are discussed as; it is time consuming, it takes a lot of resources that are sometimes not available, preparation of the review process required too much effort as well, and it is a lengthy process as well, a lengthy checklist is required to be followed, and difficult to prioritize exact activities.

The pros of review process in company A, are reducing rework and removal of assumptions. While on the other hand its cons are resource unavailability, time consumption and review is a lengthy process. The pros of review process in company B are discussed as; it shows the completeness of the requirements used in particular project and it reduces rework. The cons of review process in this company discussed as; too much documentation kills the effectiveness of the review process, it is lengthy process, time consuming and client does not

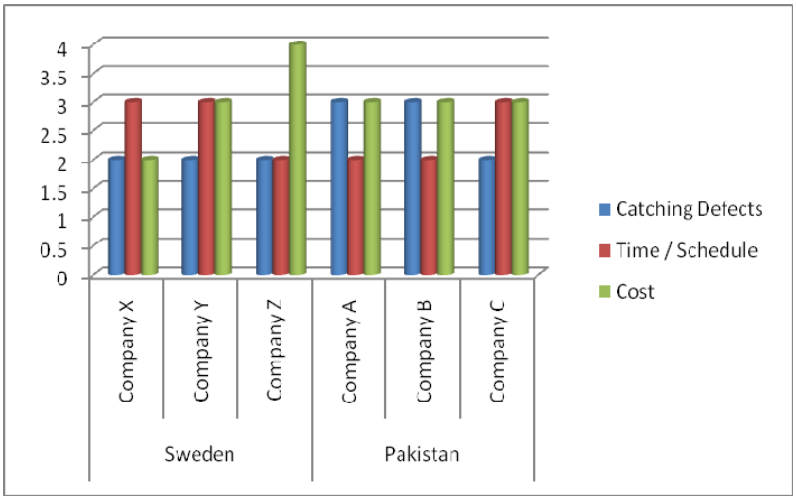
take the ownership of requirements validation. The pros of reviews in company C are discussed as; it helps to get real requirements from the customer, resolves conflicts and removes assumptions. The cons of review process in company C are: time consuming and it takes many resources.

4.3.3 SATISFACTION LEVEL OF REVIEWS

Country	Sweden			Pakistan		
Satisfaction level in terms of …	Company X	Company Y	Company Z	Company A	Company B	Company C
Catching Defects	2	2	2	3	3	2
Time / Schedule	3	3	2	2	2	3
Cost	2	3	4	3	3	3

Table 6 - Satisfactory Level of Reviews as RVTs

The satisfactory level of reviews process as requirements validation technique (RVT) in different organizations is described in table 6. This satisfaction level is discussed in terms of catching defects, time/schedule and cost. The satisfaction level as it can be depicted from graph 1 is portrayed in numbers; the highest number shows very good satisfactory level, while on the other hand the low number shows bad level of satisfaction.



Graph 1- Satisfaction Level of Reviews

4.3.4 READING TECHNIQUES FOR REVIEWS

Review process as requirements validation technique (RVT) used some specific reading techniques (as described in section 2.2.1) to go through all the documents of the requirements. As it can be seen from table 7, an ad-hoc based reading technique is used in two companies for the review process; the names of the companies are X and Y. Check-list based reading technique is used in four companies, named as Z, A, B and C for their review processes to validate the requirements of their respective projects.

Companies	Reading Techniques Used for Reviews as RVTs
Company X	Ad-hoc based Reading Technique
Company Y	Ad-hoc based Reading Technique
Company Z	Check-list based Reading Technique
Company A	Check-list based Reading Technique
Company B	Check-list based Reading Technique

Company C	Check-list based Reading Technique

Table 7 - Reading Techniques used for Reviews

4.3.5 IMPROVEMENTS IN REVIEWS

All the six companies, in which we have conducted interviews, have suggested some improvements in review process, which is used as requirements validation technique.

Companies	Suggested Improvements in Reviews as RVT
Company X	Focus should not be set only on functionality because customer needs other things as well, understand the non-functional requirements, and reviews never get to time-plans
Company Y	More time required for requirements reviews and more focus required during reviews
Company Z	Allocation of time to people who are involved in review meetings and it should be spread, checklist should be known, proper preparation of review meeting before actual meetings
Company A	As we have too much generalized checklist, it will be better if we customize check list before review meeting, instant feedback required from the customers.
Company B	More time is required, customer participation is not good because they do not want to take responsibility, and feedback required from the customers.
Company C	Pre-reviews preparation is helpful, participation of stakeholders having different backgrounds is helpful to find different perspectives of the requirements, and feedback on proposed changes from customer is required.

Table 8 - Suggested Improvements in Reviews

These suggested improvements (as given in table 8) are described in company X as; the review process does not conducted according to the time as planned, understanding of non-functional requirements is necessary so, focus should not be set only on functionality because customer needs other things as well. Company Y suggested improvements, as; there should be more time specified for requirements reviews and it is required that all members should focus on requirements validation during the review meetings.

The improvement suggestions from company Z for reviews as RVT are described as; proper preparation of review process is necessary before the actual review meetings, time should be properly allocated among the people who are involved in review meetings and this information should be spread out to all review meeting members, and check-list that is used for review process should be known already to all members. Company A has suggested the improvements for review process, as; it is better to customize the check-list before the actual review meetings, and instant feed-back from the customer is necessary.

The suggested improvements from company B are described as; more time is required for conducting the review meetings, customer participation in the review meetings is not good but feedback from customer regarding proposed changes is necessary. Company C has suggested some improvements in reviews process, which are; pre-reviews preparation is helpful for actual review meetings, participation of stakeholders having different backgrounds in the review meetings can give perspectives of the requirements, and feedback from customer on proposed changes is important.

4.4 PROTOTYPING AS RVTs

Prototyping is another requirements validation technique (RVT), which is practiced in all six companies where we have conducted interviews. In this section information related to prototyping is discussed as followings:

4.4.1 TYPES OF PROTOTYPING

Companies	Types of Prototyping used …
Company X	Throwaway
Company Y	Throwaway
Company Z	Throwaway
Company A	Throwaway and Evolutionary
Company B	Throwaway and Evolutionary
Company C	Throwaway

Table 9 - Types of Prototyping used as RVTs

According to table 9, there are two main types of prototyping for validating requirements, named as throwaway and evolutionary. Throwaway type of prototyping is used in four companies, which are X, Y, Z and C. Company A and B are using both throwaway and evolutionary types of prototyping for validating the requirements of their projects.

4.4.2 PROS & CONS OF PROTOTYPING

The pros and cons of prototyping as requirements validation technique (RVT) practiced in industry are described in table 10. The pros of prototyping in company X are discussed as; it reduces development work and reduces cost as well. The cons of prototyping in company X are described as; prototyping tends to get presentation that how it works instead of all the system and then we can add on functionality. The pros of prototyping in company Y are discussed as; take prototype and show it, speedy (Graphical interface built speedily) and instant feedback. The cons of prototyping in company Y are described as; it is costly, a lot of time and effort is required.

Companies	Pros of Prototyping	Cons of Prototyping
Company X	Reduced development work and Cost	Tend to get presentation that how it works instead of all the system and then we can add on functions
Company Y	Take prototype and show it, Speed (Graphical interface built speedily), Instant feedback	Costly, Time and effort required
Company Z	Easy to Validate, Good response and feedback	Long time, cost, need a lot of tools
Company A	Reduced development, Customer satisfaction because system developed according to the customer needs	Time Consuming, It takes time at the early stages
Company B	Visual presentation is the best way to validity in place of phrase, Customer Satisfaction, instant feedback	Time Consuming, costly (designing of prototyping is involved as well), resources unavailability
Company C	Very close to user requirements, Non technical clients can easily understand. Improved design quality	Costly: Sometimes costly to build prototypes. 2. Doesn't cover in-depth analysis.

Table 10 - Pros and Cons of Prototyping as RVT

The pros of prototyping in company Z are discussed as; it is easy to validate the requirements, good response and instant feedback from customer. The cons of prototyping in company Z are described as; it takes long time, costly and needs a lot of tools as well. The pros of prototyping as RVT in company A are described as; reduced development and customer satisfaction because system developed according to the customer needs. The cons of prototyping in company A are time consumption along with it takes time at early stages.

The pros of prototyping in company B are described as; visual presentation is the best way to validity in place of phrase, customer satisfaction and instant feedback. While the cons of prototyping in company B are: prototyping is time consuming, design cost is involved and resource un-availability. The pros of prototyping in company C are described as; it is much closer to user requirements, non-technical clients can easily understand and prototyping improves the design quality. The cons of prototyping in company C are described as; sometimes it is costly to build prototypes and it does not cover in-depth analysis.

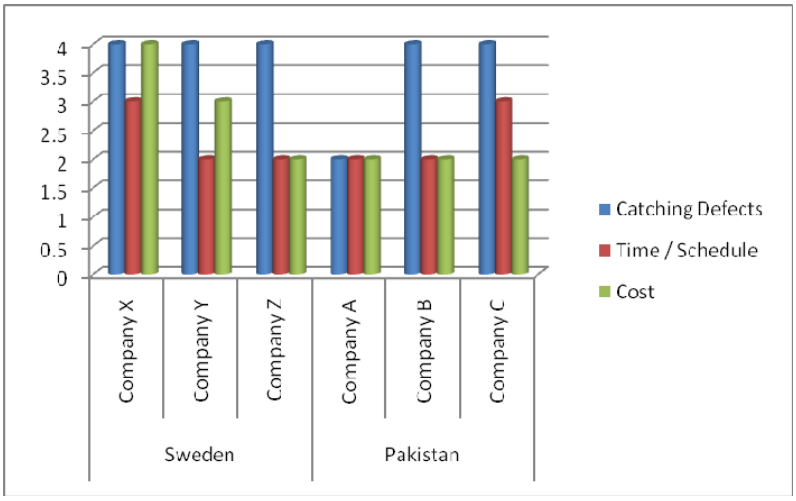
4.4.3 SATISFACTORY LEVEL OF PROTOTYPING as RVT

Prototyping as requirements validation technique (RVT) used in all six companies, the satisfaction level of prototyping in terms of catching defects, time/schedule and cost is given in table 11.

Country	**Sweden**			**Pakistan**		
Satisfaction level in terms of …	Company X	Company Y	Company Z	Company A	Company B	Company C
Catching Defects	4	4	4	2	4	4
Time / Schedule	3	2	2	2	2	3
Cost	4	3	2	2	2	2

Table 11 - Satisfactory Level of Prototyping as RVT

As it can be seen from graph 2 that five companies including X, Y, Z, B and C are very much satisfied (satisfaction level 4) regarding catching defects. But the only less satisfaction level, which is two of company A.



Graph 2 - Satisfaction Level of Prototyping

4.4.4 IMPROVEMENTS IN PROTOTYPING

The improvements suggested by all six companies in prototyping are given in table 12. The improvement suggestion from company X is that the prototyping should be part of the project plan. Company Y is suggesting that prototyping is beneficial for more of it but it should be focused on specific areas. The improvement suggestions by company Z are discussed as; sometimes it is required to acquire more tools for the development of prototyping to experiment the correctness of the requirements.

The suggested improvement by company A is that there should be proper planning for prototyping. Company B is suggesting improvements like; it is better to develop a prototyping of the application that can help at later stages to detect more defects, during presentation of the application, it may help to understand the whole application. The improvement suggestion given by company C is that it is better to convince clients to give proper time for the development of the prototyping.

Companies	Suggested Improvements in Prototyping as RVT
Company X	Prototyping should be a part of project plan.
Company Y	Beneficial for more of it, it should be focused on specific areas
Company Z	Sometimes more tools are required for developing prototyping to experiment the correctness of the requirements.
Company A	There should be a proper planning of prototyping
Company B	It is better to develop a prototype of the application that can help at later stages to detect more defects. While presentation, it may help to understand the whole application.
Company C	It is better to convince clients to give proper time for developing prototyping

Table 12 - Suggested Improvements in Prototyping

4.5 TESTING - BASED RVTs

Testing based requirements validation techniques (RVTs) are practiced in three companies, which are company Y, B and C. The following information is about testing based RVTs is given below:

4.5.1 PROS & CONS OF TESTING BASED RVTs

The pros and cons of testing based RVTs is practiced in industry are given in table 13. The pros of testing based RVT in company Y are described as; it helps to identify the real requirements, remove incompleteness and ambiguity from the requirements. The cons of testing based RVT in company Y are discussed as; many resources are used, some functions are not possible to test, for example: network failures are hard to figure out. The pros of testing based RVT in company B are described as; it gives clear view of the requirements, identify inconsistency and help to remove it.

Companies	Pros of Testing as RVTs	Cons of Testing as RVTs
Company Y	Real requirements, Remove incompleteness and ambiguity	Some functions are not possible to test e.g. network failure are hard to figure out, Resource usage
Company B	Give clear view of the Requirements, identify inconsistency and help to remove it	It takes time to create test cases for all the requirements and many resources required
Company C	Reveals problems with the requirements, Removes incompleteness , test cases are useful in later stages	Only suitable for complex systems, resource usage

Table 13 - Pros and Cons of Testing as RVT

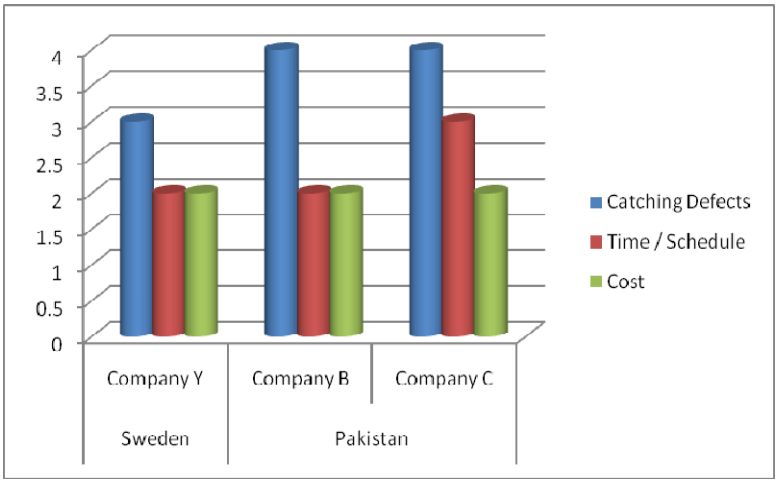
The cons of testing based RVT in company B are discussed as; it takes time to create test-cases for all the requirements and it uses many resources as well. The pros of testing based RVT in company C are given as; it reveals problems with the requirements, remove incompleteness, and test cases are useful for later stages as well. The cons of testing based RVT in company C are discussed as; it is suitable only for complex systems and it uses many resources.

4.5.2 SATISFACTION LEVEL OF TESTING

Country	Sweden	Pakistan	
Satisfaction level in terms of …	Company Y	Company B	Company C
Catching Defects	3	4	4
Time / Schedule	2	2	3
Cost	2	2	2

Table 14 - Satisfaction Level of Testing

The satisfaction level of testing based requirements validation technique (RVT) is given in table 14, in terms of catching defects, time/schedule and cost. The graph 3 shows the companies Y, B and C with their satisfaction level according to catching defects, time/schedule and cost. The satisfaction level of company B and C is highest, which is 4, while the cost of all three companies is at level 2.



Graph 3 - Satisfaction Level of Testing-based RVT

4.5.3 IMPROVEMENTS IN TESTING BASED RVTs

Companies	Suggested Improvements in Testing-Based RVT
Company Y	It is better to give proper time to Testing based RVT
Company B	Requirements are changing continuously which in result need a lot of rework. So, it better to have a mechanism that accept changes.
Company C	Proper time should be given for creating all possible test cases of the requirements; usually managers do not give proper importance to these at early stages of the application.

Table 15 - Suggested Improvements in Testing based RVT

The improvements in testing based requirements validation techniques suggested by companies Y, B and C are given in table 15. The suggested improvement given by company Y is that it is better to give proper time to testing based RVT for validating the requirements.

The improvement suggestion proposed by company B is discussed as; requirements are changing continuously which in result requires a lot of rework. So, it is better to develop a mechanism that accepts changes in requirements. Company C is suggesting improvements like; usually managers do not give proper importance to create all possible test cases for all the requirements, proper time should be given to test cases in testing based RVTs.

4.6 MODEL - BASED RVTs

Model based requirements validation technique (RVT) is used only in two of the companies, in which we have conducted interviews. Some information related to model based RVT is given below:

4.6.1 MODELING TECHNIQUES USED AS RVTs

There are different kinds of modeling techniques (as discussed in section 2.4) used for model-based requirements validation. Company X uses simulations as modeling technique for validating the requirements of their projects. However as given in table 15, company C used data flow diagrams (DFDs) and UML (unified modeling language) diagrams for validating the requirements of their projects.

Companies	Modeling Technique Used
Company X	Simulation
Company C	Data Flow Diagram, UML

Table 16 - Practiced Modeling Techniques

4.6.2 PROS & CONS OF MODEL BASED RVTs

Companies	Pros of Model as RVTs	Cons of Model as RVTs
Company X	Cost Saving, remove assumptions and remove requirements risk	Time Consuming, There is a risk that wrong simulation results can lead to a wrong results and it should be more detailed results
Company C	Overview of the entire system and link between their subsystems, Requirements Consistency.	More Technical, Difficult to understand for the customer, Time consuming

Table 17 - Pros and Cons of Model based RVTs

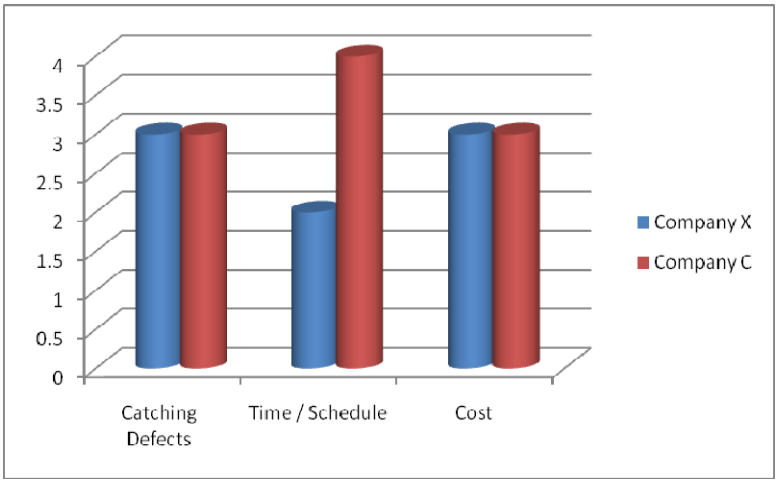
The pros and cons of model-based requirements validation technique (RVT) are given in table 17. The pros of model-based RVT in company X are described as; it is cost saving, removes assumptions and it removes requirements risks as well. While on the other hand the cons of model-based RVT in company X are: it is time consuming, there is a risk that wrong simulation results can lead to wrong requirements results, and it should be more detailed. The pros of model-based RVT in company C are discussed as; it gives an overview of the entire system and link between their subsystems and it gives consistency between the requirements. The cons of model based RVT in company C are given as; models are more technical, difficult to understand for the customers and time consuming as well.

4.6.3 SATISFACTORY LEVEL OF MODELING

Satisfaction level in terms of …	Company X	Company C
Catching Defects	3	3
Time / Schedule	2	4
Cost	3	3

Table 18 - Satisfactory Level of Model based RVTs

The satisfactory level of modeling based requirements validation techniques (RVTs) in terms of catching defects, time/schedule and cost is given in table 18. The graph 4.4, shows catching defects, time/schedule and cost of model based RVT used in companies X and C. For instance, satisfactory level with respect to catching defects and cost in both organizations is at level 3 however, satisfaction level regarding time/schedule is deviating from 2 to 4 in both organizations.



Graph 4 - Satisfaction Level of Model-based RVT

4.6.4 IMPROVEMENTS IN MODEL-BASED RVTs

Companies	Suggested Improvements in Testing-Based RVT
Company X	Simulation on service level and it should come to lower level (hardware level)
Company C	Mostly model-based RVT is used for functional requirements, it is equally important to consider models for non-functional requirements as well.

Table 19 - Suggested Improvements for Model-based RVTs

The improvement suggestions for model-based requirements validation technique are given in table 19. Simulations are used as model-based RVT in company X, the organization is using simulations on service level and it is suggesting that simulations should be bring down to lower level of hardware as well. The suggested improvement for model-based RVT in company C is described as; this RVT is mostly used for functional requirements, but it is necessary to be considered for non-functional requirements as well.

4.7 REASONS TO SELECT RVTS

Companies	Techniques we know…	Most suitable in our scenario	Our Favorite Techniques	Others…
Company X				Old habit of doing things
Company Y		*		
Company Z		*		
Company A				Part of our process and CMMI requirement
Company B		*		These are part of our Process
Company C	*			

Table 20 - Reasons behind the Selection of RVTs

The reasons behind selection of requirements validation techniques (RVTs), in the organizations where we have conducted interviews are given in table 20. Companies including Y, Z and B have selected the RVTs, which are most suitable for their requirements

scenarios. Company X is selecting RVTs according to their old habit of doing things. Company C is using RVTs, which they know but company A is using RVTs, which are part of their CMMI processes.

4.8 REQUIREMENTS VALIDATION TIME

Companies	Requirements Validation Time As Compared To The Total Time of The Project
Company X	5 - 10%
Company Y	6%
Company Z	5 - 7%
Company A	5%
Company B	8%
Company C	5 - 10%

Table 21 - Requirements Validation Time

The time that is spent on requirements validation as compared to the total time of the project is given in table 21. Company X is spending 5 to 10% of the time for validating the requirements as compared to the total time of their particular projects project. Company Y is spending 6% of the time to requirements validation as compared to the total time of the project. Company Z is spending 5 to 7 % of its time on requirements validation as compared to the total time of the project completion. Company A is utilizing 5% of its project completion time to requirements validation. Company B is spending 8% of the time for validating the requirements, while company B is spending 5 to 10% of the time to requirements validation as compared to the total time of the project completion.

5. DATA ANALYSIS

Summary

The analysis of interview results is done from different perspectives and it combines different factors together to find relationship among them. Thesis report is an attempt to find suitable answers for research questions and data is analyzed according to the research questions as well. There are many requirements validation techniques (RVTs) presented in academia but according to this study five RVTs namely reviews, prototyping, testing-based and model-based RVTs are practiced in industry. The pros and cons of each of the RVTs are discussed and analyzed. RVTs help to identify consistent, complete, correct and clear requirements. Comparison of different RVTs that are practiced in industry analyzed and discussed. Requirements reviews, prototyping, testing based and model based RVTs are comparatively analyzed. The differences in requirements validation techniques practiced in Pakistani and Swedish software industry are discussed and same RVTs are analyzed again with respect to both of the countries.

INTERVIEW ANALYSIS

Authors have observed that most important activities while preparing this report are interview study design, conducting interviews and data analysis. Authors collected a lot of data during semi-structured interviews. But authors are presenting only those answers, which are directly or indirectly relevant to the research questions. Authors are reducing less important data from the interview results very carefully, just for sticking back to the research questions. Here, it is essential to note that authors do not want to eliminate any important information as well. After collecting data from interviews, authors have done analysis from different perspectives and combined different factors together to get the relationship in between them. The combined factors are related to each other and give different point of views of the obtained results.

Authors used white-board for discussing important points of the interviews during their group meetings. Before conducting actual interviews and data analysis, authors took different practice sessions for the preparation of interviews and data analysis. For example: authors conducted interviews with their fellow students who have already worked in this area of requirements. The data collected from these interviews was helpful to refine interview questionnaire (as discussed in section 3.4) and for data analysis as well. This chapter of thesis report is an attempt to find the suitable answers for the research questions (which are identified in section 1.3) with the help of interview results, analyzing the data obtained from interviews, and finding relations between different results.

5.1 RESEARCH QUESTIONS AND DATA ANALYSIS

This analysis section, explores different perspectives of the interview results to satisfy given research questions. The links between interview questionnaire (see, Appendix 1) and research questions will help to pursue different directions of analysis, for discussing information regarding requirements validation techniques (RVTs). The interview results (see, chapter 4) are presented according to the flow of interview questionnaire. Now, data analysis is presented according to the research questions. The data analysis of the different interview questions will be used to answer for one single research question or may be for multiple research questions.

The data analysis is done according to the flow of research questions. Interview results simply presents the results of interviews questions; now in this section, authors analyze the results, and combine related factors of the results to answer the research questions. Combine factors are the common results, which are extracted from the interview results. The following sections are presenting data analysis for each and every research question. The research questions are referred to as RQs explicitly, for example: RQ1 means research question number 1 and so on.

5.2 RQ1 & Data Analysis

> RQ1- What are the requirements validation techniques available in the literature?

Authors tried to give the answer of this question, in the form of a short literature survey, of commonly available requirements validation techniques (RVTs), which are presented in chapter 2. Table 22 shows commonly known RVTs, which are presented in academia:

No. of RVTs	Requirements Validation Techniques (RVTs) Presented in Academia
1	Requirements Pre-Reviews
2	Reviews as RVTs
	a. Requirements Inspection
	1. Test-Case Driven Inspection
	b. Reading Techniques
	1) Ad-hoc based Reading
	2) Check-list based Reading
	3) Perspective based Reading
3	Prototyping as RVTs
	a. Throwaway Prototyping
	b. Evolutionary Prototyping
4	Model-based Requirements Validation
	a. Data-Flow-Diagrams
	b. Compositional Models
	c. Classification Models
	d. Process Models
	e. Simulation Models
5	Testing-based Requirements validation Techniques
6	Viewpoint-oriented Requirements Validation

Table 22 - Commonly known RVTs Presented in Academia

5.3 RQ2 & Data Analysis

> RQ2- What are the requirements validation techniques used in different organizations in Sweden and Pakistan?

The answer of this research question is given in chapter 4 of interview results. Authors observed that there are different requirements validation activities and processes, practiced in organizations, in which authors have conducted interviews. Sometimes personnel involve in validating the requirements; do not exactly know the names and terminologies of the activities and processes, which they are using. After conducting interviews, authors have identified that followings are the commonly practiced requirements validation techniques (RVTs) in software industry:

1. **Pre-Reviews** : Six out of six companies are using Pre-reviews
2. **Reviews**: Six out of six companies are using Reviews
3. **Prototyping**: Six out of six companies are using prototyping
4. **Testing-based RVTs**: Three out of six companies are using Testing-based RVT
5. **Model-based RVTs**: Two out of six companies are using Model-based RVTs

Authors observed the requirements validation process of all six companies, in which they are using requirements pre-reviews, reviews and prototyping as their requirements validation techniques (RVTs). These are the most commonly practiced RVTs in industry now-a-days. There are only three companies; company B and C from Pakistan, and company Y from Sweden, are using testing-based RVT. Model-based RVTs are used in only two companies, one from each of the country, which are company X and C. Company X in Sweden is using simulations as modeling technique, while on the other hand company C in Pakistan is using data-flow and UML models as there RVTs.

5.4 RQ3 & Data Analysis

> RQ3- What are the pros and cons of requirements validation techniques used in software industry?

Authors directly asked questions regarding pros and cons of particular requirements validation techniques (RVTs) used in different organizations. Here, pros are known as the benefits and advantages of the specific RVT used. While on the other hand, cons are the disadvantages and shortcomings of the same RVT.

5.4.1 Pros & Cons of Requirements Reviews

The review process is used as requirements validation technique (RVT) in all six companies. The results of interview questions related to pros and cons of reviews are presented in section 4.3.2, which are further discussed and analyzed as following:

1. **The pros of requirements reviews** in all companies are mostly same except few of them, as given below.

2. Requirements review process involves people from different departments and backgrounds in the actual review meetings (see section 4.3.1). In other words, different experiences get together for identifying problems exist in the requirements, which can be considered from different perspectives. For instance, software developers, testers, project managers, and customers all have their own specific point of view that can be different from each other. These review meetings can help the participants to enhance their knowledge by learning from each other's experience. All the participants of the review meetings can share their views on specific requirements, which are required to be discussed and analyzed. This way of reviewing the requirements document is considered to be easy and educational for many of the participants.

3. As different experiences are gathered for considering each of the requirements, it is easy to expose problems with the requirements, quickly. Requirement reviews help to identify existing defects and conflicts among the requirements. After identifying the defects and conflicts, ways of removing and resolving these defects and conflicts are chalked out. These defects and conflicts are removed according to the agreed ways. Removing the conflicts among the requirements provide consistency and completeness of the requirements.

4. Requirements review meetings can help its participants in many ways, for example: project manager gets a lot of help in determining detailed schedules. It helps to give better estimates for implementing these requirements. Along with this, review meetings can also help to suggest possible budget of the overall software project. And it can assist project managers, to properly distribute resources on upcoming system implementation.

5. The existing problems related to interdependent requirements can be identified during the review meetings. These meetings can also help in prioritizing the requirements for upcoming system development.

6. Authors observed that review meetings can help in removing assumptions, which exists in the requirements. Assumptions are made when the requirements are not clear and consistent. As some of the companies are doing offshore development (see, section 4.1), so in this case, clients/stakeholders are at remote places. It makes difficult to involve them in the review meetings. But all other participants of review

meetings discuss and analyze the requirements for which assumptions are made. By removing these assumptions of requirements help to clarify the requirements. Requirements reviews process helps to save a lot of re-work and implementation time as well just due to removal of assumptions from the requirements.

7. **The cons of requirements reviews** in all six companies are also same with exceptions. The cons of reviews as RVT are given as followings:

8. Authors observed that most of the companies spend a lot of time on requirement reviews and it is lengthy process as well. Before actual review meetings, time is spent on different activities for preparing review process. Most of the times stakeholders, who are involved in review meetings, do not come with proper preparation. They also take time to understand the requirements during review meeting which waste lot of time.

9. Review process involves too much documentation that sometimes kills the effectiveness of the review process. But authors cannot neglect the importance of it, if companies give proper time to requirements reviews for validation of the requirements, and do proper preparations for review meetings as well then they can save a lot of time.

10. It is difficult to follow lengthy check-lists during the review meetings, which may cause difficulties to exactly prioritize all the activities. Most of the check-lists used in review meetings are too generalized, which requires more time to read and follow because of its irrelevant portions included in the check list. It is suggested that checklists should be precise, customized and up to date according to project needs.

11. Authors observed that review process takes a lot of resources as well. Sometimes, it is very difficult to involve people from different departments in the review meetings because they may have their own commitments and scheduled deadlines. It is difficult to gather them on the same time. Sometimes, review meetings are conducted in different sessions and people involvement is difficult in this scenario as well. So, resource availability is one of the main issues as well. There should be a proper time allocation for each of the resource involved in review meetings.

12. Requirements review process has some risks associated to it, for example: too much emphasis on one kind of the requirements can cause problems of equal time/schedule and resource division other requirements.

5.4.2 Pros & Cons of Prototyping as RVT

Prototyping as requirements validation techniques (RVTs) is practiced in all six companies, in which we have conducted interview studies. The results of questions related to pros and cons of the prototyping are presented in section 4.4.2 of interview results. The discussion and analysis related to pros and cons of prototyping as RVTs are followings:

1. **The pros of prototyping** as RVT in all six companies are mostly same except few of them, as given below.

2. Prototyping is actually visual presentation, which is an easy way to involve customers in validating requirements. It helps to get instant feedback from the customer and also understandable to non-technical customers (see section 4.1) as well. Most of the times customers are unaware of their system requirements and they do not have too much technical knowledge, in this case prototyping is more beneficial as compared to other validation techniques.

3. Prototyping as RVT can develop graphical user interfaces (GUIs) speedily, which help to show overall system to the customers. Customers feel satisfaction after having the overview of the system that how it will work after its completion. Prototyping is much closer to the user requirements and it helps to improve the quality of the requirements and GUI design as well.

4. Prototyping as RVT reduces a lot of development re-work, which in result reduces time and cost, just because of finding correct and consistent requirements. It is always better to check the completeness, correctness, and consistency of the requirements, before developing the whole system on them. In this way, companies save a lot of development effort along with time and cost. For example: if any system developed on ambiguous and vague requirements then at the end of the day it reveals that most of the development effort went into the wrong directions and it is needed to be fixed. So, new time schedules will be required to get the system right, along with extra cost and resources.

5. **The cons of prototyping** as RVT in all six companies are mostly same except few of them, as given below.

6. Authors observed that for developing prototyping as RVT requires too much development efforts. Sometimes prototyping is discarded after validating the requirements and then product is built again from the scratch. But in case of evolutionary prototyping the whole project is evolved on the same developed prototype. Sometimes customer demands too many changes after having the product, which also increase the time/schedule and cost of the project.

7. Authors observed that prototyping gives an overview of the whole system, which shows flow of the system that how it will looks like. The development of the prototyping requires too much time at early stages of software development lifecycle. Most of the times prototyping is discarded after validating the requirements, in other words the whole product is required to be developed from the beginning again, which seems to be costly as well.

8. Authors observed that some of the companies consider prototyping costly because clients do not give proper time for validating the requirements (see section 4.4.4) and as a result defects remains in the prototype. These defects are seeded into the next stages of SDLC which may affect other requirements as well. The defects which are detected at later stages are comparatively expensive than the defects detected at early stages of SDLC.

9. Prototyping as RVT is only an overview of GUI presentation of the system that sometimes tell the flow of system rather than describing in-depth details of the system. Prototype tells that how the system will work instead of giving detailed information that how and what functionality can be added on as next stages of SDLC comes.

5.4.3 Pros & Cons of Testing-based RVTs

Testing based requirements validation techniques (RVTs) are practiced in three of the companies (one from Sweden and two from Pakistan), in which we conducted interview studies. The results of questions related to pros and cons of testing based RVTs question are given in section 4.5.1. The pros and cons of testing based RVTs are analyzed as followings:

1. **The pros of testing based RVTs** in three out of six companies are discussed as given below.

2. Authors observed that testing based validation of the requirements starts at the initial stages of software development lifecycle but actual tests of the system are executed after its completion. Testing based RVT identifies testable requirements of the system. Testable requirements are those which have test-cases associated to it. Some of the requirements may have multiple associated test-cases.

3. Test-case creation for any of the requirement exposes all of its relevant information. A test-case creation reveals possible problems exhibited in a specific requirement. The identified problems of specific requirement help to find out real requirements of the system. So, if there any problem occurs in creating the test-cases for a requirement then it may indicates that this requirement is not complete and it is inconsistent or ambiguous. This problem can be missing of information or description of the requirements does not portray what exactly is required from it.

4. Authors observed that by solving requirements problems, which are identified with the help of test-case creation, the ambiguity, incompleteness, and inconsistency of the requirements can also be removed. Test case of the requirements gives a clear view of the requirements. The created test cases of the requirement are also helpful at the later stages of SDLC, which helps to test the developed system according to the test cases of the requirements.

5. **The cons of testing based RVTs** in three out of six companies are discussed as given below.

6. Authors observed that testing based RVT is a time consuming process. It takes time to create test-cases of all the requirements at the beginning of project. Sometime requirements of the system require multiple test-cases, which takes more time. When we create test-cases for each of the functional requirement, these requirements are thoroughly analyzed before defining the test-cases to check if system satisfies its requirements or not.

7. Testing based RVT needs resources for validating the requirements at early stages of SDLC. Resources are usually busy in their already scheduled tasks and mostly quality assurance resources (for instance software testers) tests the end- products. But test-cases are created at early stages of SDLC; sometimes it is difficult to find quality assurance personnel in early stages of software development. Sometime project managers do not see the importance of spending time at test-case creation in testing-based RVT (see, section 4.4.4). It is suggested that companies should spend time in testing based RVTs to acquire consistent, complete, clear and correct requirements for developing the system.

8. Sometimes it is not possible to create test-cases for all the functional and non-functional requirements. For example: non-functional requirements like, network failures are hard to figure out. We observed that mostly test cases for non-functional requirements are considered difficult.

9. Along with this, one of the companies considered that testing based RVTs are only suitable for complex systems where all requirements required to be tested individually and carefully. The example of complex system can be like modern telecommunication infrastructure where we cannot bear any problems.

5.4.4 Pros & Cons of Model-based RVTs

Model based requirements validation techniques (RVTs) are practiced in two of the companies (one company from each of the countries), in which we have conducted interviews. The results of pros and cons of model based RVTs are presented in section 4.6.2, the pros and cons of model based RVTs are analyzed as following:

1. **The pros of model-based RVT** in two out of six companies are discussed as given below.

2. Authors observed that simulations as modeling technique for validating the requirements are used in one of the two companies, which are using model-based RVT. The company that is using simulations working in telecom sector. Simulations as model based RVT is cost saving in a way that it helps to remove unforeseen bottlenecks by simulating real requirements.

3. With the help of simulation as a modeling technique, company recognizes the implementable requirements and refines the non-implementable requirements. Along with this, it removes assumptions from ambiguous requirements. Model based RVT helps to reduce risks associated with the requirements.

4. Authors observed that UML and DFDs (data flow diagrams) are used as model based RVT. These modeling techniques give an overview of the entire system and links in between their subsystems as well.

5. This modeling technique provides consistency of the requirements as well. For example: entities of the system and sub-system are well known, which are going to be modeled.

6. **The cons of model-based RVT** in two out of six companies are discussed as given below.

7. Authors observed that model based RVT consumes a lot of time, while simulating all the requirements. There is a very big risk that wrong simulation can lead to wrong requirements results. Simulation for each of the requirement is required to be more detailed, so it involves time and cost as well.

8. Model based RVT is more technical, so may be difficult to understand for the customers. While developing requirements models it takes a lot of time as well. This company involves customers for model validation, which is normally difficult for the clients to understand the models, so it would be better that they use natural language to define these models.

5.5 RQ4 & Data Analysis

RQ4. What is the comparison of different requirements validation techniques practiced in industry?

RQ4.1	How much specific requirements validation technique is good in terms of catching defects?
RQ4.2	How much specific requirements validation technique is good in terms of time/schedule?
RQ4.3	How much specific requirements validation technique is good in terms of cost?

This research question is related to the comparison of different requirements validation techniques (RVTs), used in industry. This comparison is done in three areas, which are catching defects, time/schedule and cost. Authors are comparing and analyzing multiple RVTs in this section of the report. The purpose of these questions is to find out which requirements validation technique is the cheapest or expensive and which one is catching most of the defects. Authors are comparing different RVTs on the basis of cost, time/schedule, detecting defects and other related factors, which are gathered during the interview studies. The comparison is based on the collected data, which is presented in chapter 4 of interview results.

Authors have observed that it is very difficult to extract intangible information from anyone, for example: how much you are satisfied in terms of catching defects? It seems to be difficult to express ones' satisfaction level in qualitative terms. So, for extracting this kind of information in quantitative numbers, authors have developed some specific questions that directly get information in terms of numbers. Through quantitative questions, authors asked the satisfaction level in terms of catching defects, time/schedule and cost. All the relevant information regarding particular RVTs is described under their specific headings, as followings:

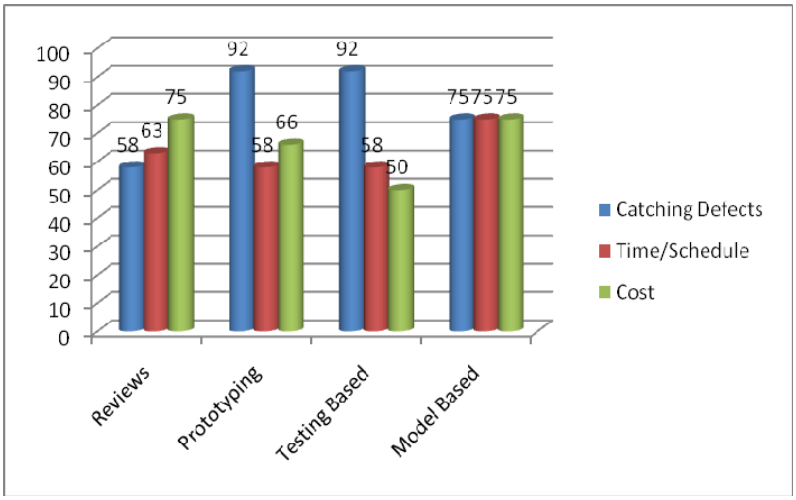
5.5.1 Comparison of different RVTs

The information regarding satisfaction level is collected on the scale of 1 to 4, where 1 is bad and 4 is very good. Authors have converted the scale of 1 to 4 into the scale of 1 to 100, for comparing different interview results, for instance:

"Bad ---- 1|---- 2|---- 3|---- 4| Very Good"
"Bad ----25|----50|----75|----100| Very Good"

The graph included in this comparison, is portraying the average results of satisfaction levels of specific RVTs, used in different companies. The average result of specific RVT is calculated based on the companies, in which it is used. For example, reviews as RVTs, used in all six companies, where authors have conducted interview studies. So, the average result for review is calculated based on the data collected from all six companies.

The higher number of a particular term in specific RVT is expressing higher satisfaction, while lower number is showing exactly vice versa appreciation. The comparison of different RVTs with respect to their capability of catching defects, time/schedule spent on it, and the cost for each of the RVTs is portrayed in Graph 5.



Graph 5 - Comparison of different RVTs

5.5.1.1 Catching Defects

a) The authors observed that prototyping and testing-based RVTs are catching most of the defects, which are 92 percent in numbers. This means these two RVTs are very much respected in terms catching defects as compared to other RVTs used. Along with this information, Graph 5 also represent that for catching most of the defects, these RVTs are spending most of the time, and most of the cost as well.

b) Authors observed that reviews as RVT is catching least (minimum) defects, which is 58 percent in numbers, as compare to any other requirements validation technique. Here, it is important to note that if requirements reviews are catching fewer defects than at the same time, they are using less time and cost as compared to prototyping and testing based RVTs.

c) Model-based requirements validation technique is catching more defects as compared to requirements reviews, which is 75 percent in numbers but at the same time, its speed of catching defects is lower than the catching defects of prototyping and testing based RVTs.

5.5.1.2 Time/Schedule

a) Authors observed that prototyping and testing-based RVTs are most time consuming requirements validation technique as compare to all other RVTs, which is in 58 percent in numbers. This means that companies are not much satisfied with prototyping and testing based RVTs in terms of time/schedule. Because they spent most of their requirements validation time on prototyping and testing based RVTs.

b) Authors observed that model-based RVT is taking least (minimum) time, which is 75 percent in numbers, as compare to all other requirements validation technique. This means that the companies used model-based RVTs, are very much satisfied in terms of their time/schedule, in-fact their satisfaction level (in terms of time/schedule) is higher as compared to all other RVTs.

c) Requirement reviews as RVTs, are spending minimum time, as compared to prototyping and testing-based RVTs, which is 63 percent in numbers. But this number is lower than the satisfaction level of model-based RVTs.

5.5.1.3 Cost

a) Authors observed that requirements reviews and model-based are the cheapest RVTs as compared to prototyping and testing based RVTs, which is 75 percent in numbers for both the RVTs. Model-based RVT is more economical of all the RVTs because it is cheapest while spending minimum time for catching defects.

b) As Graph 5 portrays, testing-based RVT is most expensive in terms of cost as compared to all other RVTs. Here, it is essential to note that satisfaction level of testing based RVT is 50 percent, which means that the companies using testing based RVTs are spending too much money on it. But at the same time they are benefited with catching most of the defects through this RVT.

c) Authors observed that prototyping is cheaper in cost as compared to testing based RVT, which is 66 percent in numbers. But at the same time prototyping is expensive as compared to reviews and model based RVTs. As it is already mentioned that prototyping along with testing based RVT are best for catching defects while validation the requirements.

5.5.2 RVTs' Specific Discussion

It is always better to find solutions for the problems existed in requirements document. The cost of detecting and fixing defects of requirements in the later stages of SDLC (software development life cycle), is comparatively much higher than the cost of detecting and fixing defects at early stage [11], of requirements. A brief discussion about specific RVTs is presented in this section.

5.5.2.1 Reviews as RVTs

Graph 5 illustrates satisfaction level of reviews as RVT; it shows that the satisfaction level in terms of cost is better as compared to the satisfaction level of time/schedule and catching defects. Sometimes companies are facing problems in finding and placing proper resources for review meetings. Review meetings involve different stakeholders from their respective departments; it is difficult to gather all of them at the same time. Stakeholders from different backgrounds come in review meetings without proper preparations and planning. This kind of activity minimizes the effectiveness of the review meetings along with the chances of catching more defects. The companies think that requirements review process is a time consuming and lengthy process (see, section 4.3.2).

5.5.2.2 Prototyping as RVTs

Prototyping as RVT is catching most of the defects as compared to the percentage of cost and time/schedule spent on it. The satisfaction level of prototyping in terms of catching defects is higher because of its visual presentation. This is an easy way to get immediate feedback and response from the customer and even from non-technical clients as well. They can help in detecting more defects by giving prompt response after viewing the prototype.

Authors observed that companies are spending more time on prototyping. This is because of its lengthy process of developing GUIs (graphic user interfaces) and other related development efforts. After developing the systems' overview, the clients are involved, for the purpose of getting feedback from them. This is why prototypes are taking too much time/schedule. Along with this, authors observed that prototyping is comparatively an expensive RVT considering the percentage of catching defects. This cost is escalated because of time consumed on developing efforts, which also occupied certain resources.

5.5.2.3 Testing-based RVTs

Authors observed that in testing-based RVT the percentage of catching defects is very high than the percentage of the time/schedule and cost that is spent on validating the requirements. Test cases for each of the requirements are generated in testing based RVT, which exposes defects and problems exist in the requirements. Authors observed that testing based RVT costs more to catch defects because requirements are changing continuously, which requires a lot of re-work along with extra time for developing test cases. If time/schedule of the project exceeds from its scheduled time and date, it obviously costs more budget to spend on it for rebuilding.

5.5.3 Model-Based RVTs

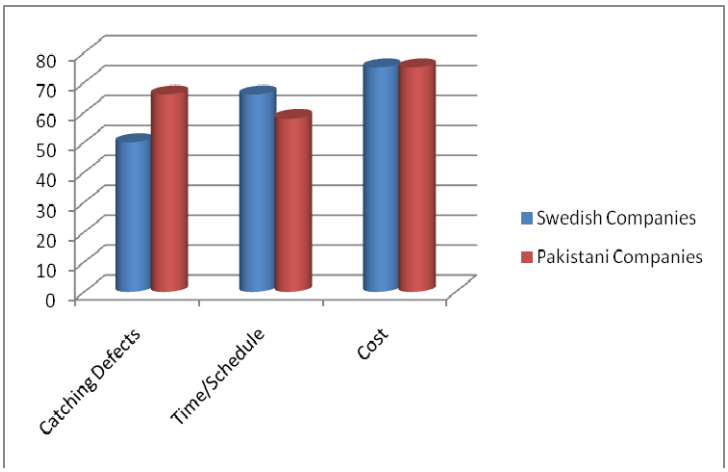
Authors observed that in model-based RVT catching defects, time/schedule and cost, are percentage-wise at the same level. Model based RVT are easier way for developers to extract the missing information from the requirements. It reduces risks that are associated with the requirements, clarify the requirements, and improve the consistency among them.

5.6 RQ5 & Data Analysis

> RQ5. What are the differences in requirements validation techniques practiced in Pakistani and Swedish software industry?

This research question is emphasizing on identifying the differences in requirements validation techniques (RVTs) practiced in the software industry of Pakistan and Sweden. Authors conducted interview studies in different organizations of both the countries; this is an attempt to find out answers for this research question. Authors are analyzing and comparing available RVTs according to different organization in both of the countries. The graphs presented in this section, are representing the country wise average results of satisfaction level of specific RVTs. This average result is calculated based on the results provided by companies in both of the countries.

5.6.1 Reviews as RVTs

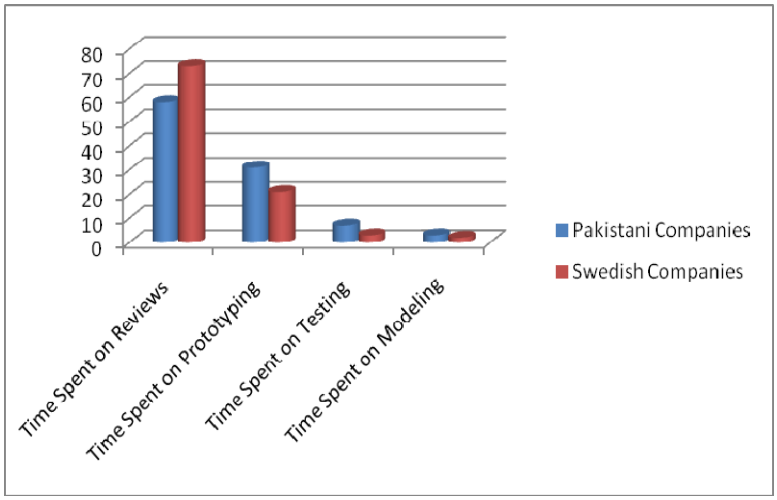


Graph 6 - Country-wise Satisfaction of Reviews

1. Pakistani companies are finding more defects as comparing to Swedish companies, in requirement reviews, as shown in Graph 6. It is interesting to note that Pakistani companies are spending less time on requirements reviews as compared to Swedish companies (see Graph 7). One of the issues for catching more defects in Swedish companies is resource unavailability (see, section 4.3.2) at the time of review meetings, as compared to Pakistani organizations. In-fact Swedish companies have more resources than Pakistani companies but sometimes their availability for review meetings is difficult. This might be due to their already scheduled timelines for existing projects. As review meetings involve different stakeholders from their respective departments; it is difficult to gather all of them at the same time. Generally, for the review meetings, they all come without proper preparations and planning. This kind of activity minimizes the effectiveness of the review meetings.

2. Most of the Swedish companies are using ad-hoc based reading technique for reviewing the requirements documents while on the other hand most of the Pakistani companies are using check-list based reading techniques (see, section 4.3.4). Ad-hoc based reading technique provides little support for reading and defect detection [25], which is mostly depending on the knowledge and experience of the reviewers. Swedish companies can catch more defects by using check-list based reading technique during the review meetings. But here, it is important to note that check-lists should be customized, concise and according to the given projects (see, section 4.3.5). Otherwise too much generalized check-lists will be difficult to follow.

3. Authors observed that customer participation in review meetings in Pakistani companies (see, section 4.1) are beneficial but at the same time it might be time consuming activity (see, section 4.3.2). This activity is beneficial in a way that customer gives instant feedback when they understand the requirements. If customers are unaware of their requirements and do not have in depth knowledge, then they need assistance from other stakeholders to understand those specific requirement statements. It increases the time, which is already scheduled for the review meetings. So, we can say that it may take little longer time but it is beneficial for catching more defects.

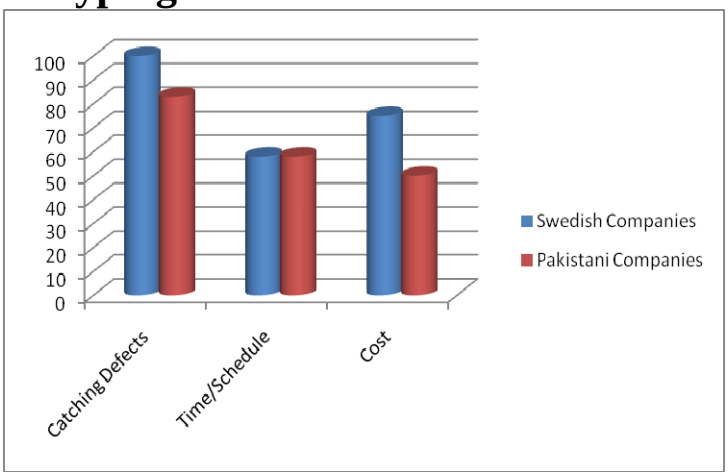


Graph 7 - Country-wise Time spent on different RVTs

4. Both Swedish and Pakistani companies think that requirements reviews are cheap in cost for validating the requirements (see, Graph 6). Companies think that requirement reviews as RVTs are comparatively easy to conduct for

removing defects from the requirements. This is because they already have the resources, which are required to review the requirement documents. The defects which are detected at early stages of SDLC are comparatively much cheaper in cost as compared to the cost of detecting and fixing the same defects detected at later stages.

5.6.2 Prototyping as RVTs



Graph 8 - Country-wise Satisfaction of Prototyping

1. Swedish organizations are catching more defects than Pakistani companies, as it can be seen from Graph 8. Companies of both the countries are spending equal time on requirements prototyping. Sometimes in Pakistani companies, clients do not give proper time for developing the prototype, which in result creates problems in validating the requirements. When companies deliver prototype to the clients then most of the times they give less time to prototype validation. Their late feedback might affect catching most of the defects at this stage, which creates problems at later stages of SDLC. So, it is suggested that companies should create a proper plan for prototyping as well (see, section 4.4.4).

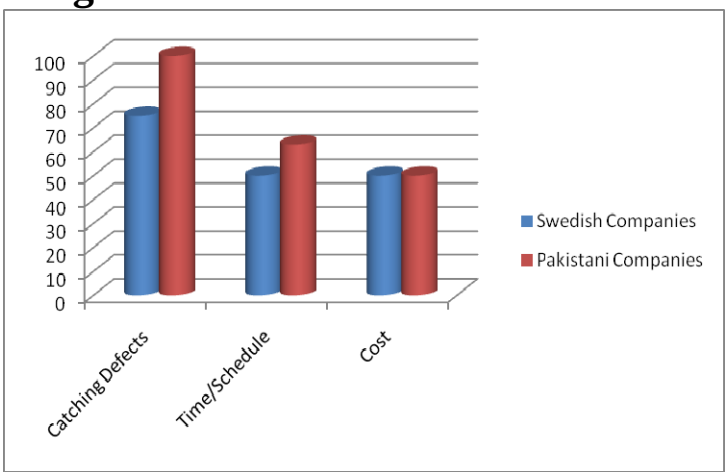
2. There is a difference in development of the prototype, in companies of both countries, for instance: most of Pakistani companies are developing both evolutionary and throwaway prototyping technique, whereas Swedish companies are only using throwaway prototyping technique (see, section 4.4.1). The reason for this is that most of the Swedish companies are doing market driven projects and after validating the requirements they discarded the prototype (see, section 4.1). Whereas Some Pakistani companies are doing offshore development and for the customers who are not aware of their requirements so in that particular scenario evolutionary prototyping suits.

3. Companies in Sweden and Pakistan might think that requirements prototyping is a time consuming activity. This would be due to development efforts required for prototype. Authors observed that some of the companies are suggesting that prototyping should be part of the project plans (4.4.4). If companies include prototyping in their project plans and manage their projects properly (means properly allocate resources, budget and time for it). It certainly will help to enhance detailed schedules of the projects for improving the development of the project within given timeframe.

4. Authors observed that Swedish companies might think that their prototyping process for validating the requirements is comparatively cheaper than Pakistani

companies. This might be due to their usage of only one type of prototyping (throwaway), which consumes less time as well. While on the other hand Pakistani companies are using both types of prototyping, which comparatively consumes more time. That is why Swedish companies are comfortable with the cost of prototyping for validating the requirements.

5.6.3 Testing based RVTs



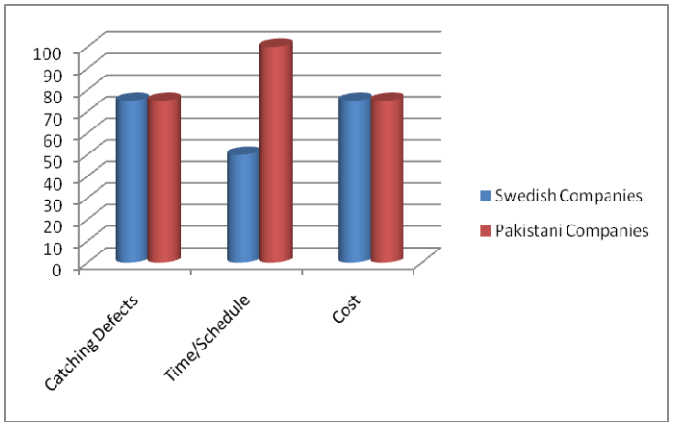
Graph 9 - Country-wise Satisfaction of Testing-based RVT

1. Authors observed that in testing-based requirements validation technique Pakistani companies are catching more defects as compared to Swedish companies, as shown in graph 9. Here the point of interest is that there are two companies using testing based RVTs while only one Swedish company using this RVT. It is interesting to look that Pakistani companies are spending more time for catching most of the defects. Authors observed that there should be a proper mechanism that accepts continuous changes in the requirements (see, section 4.5.3). Changes in the requirements create a lot of re-work, which in results requires extra time/schedule and resource to complete it.

2. Authors observed that cost of catching defects through testing based RVT is same in companies of both the countries. Testing-based RVT is more suitable for complex systems, where test cases for every requirement are required to be generated very carefully. Testing based RVT consumes times and resources for creating test-cases of each of the requirements.

5.6.4 Modeling based RVTs

Authors observed that through model-based RVT, catching defects and cost for catching these defects are equal in Swedish and Pakistani companies, as given in Graph 10. But Pakistani company is spending more time on model-based RVT as compared to Swedish company. Here, it interesting to know that Pakistani company is using DFDs (data flow diagrams) and UML (unified modeling language) diagrams for modeling the requirements, while on the other hand Swedish company is using simulation as their modeling tool. This is difference in usage of modeling tools is because of the different domain of both the companies (see, section 4.1). Swedish company is working with very complex system and they need result of their system before implementation. That is why they are using simulations for modeling the requirements of the system.



Graph 10 - Country-wise Satisfaction of Model-based RVT

5.6.5 Related Cultural Discussion

1. Authors observed that during requirements review meetings, Pakistani companies mostly involve senior people like: project manager and team lead etc. Whereas Swedish companies mostly involve stakeholders from different departments including senior people as well. It is a cultural thing that only senior people are involved in the process of requirements validation in both of the countries. While conducting our interview meeting, we observed that in Pakistani organizations the environment of formal aptitude is respected. Whereas in Swedish organization the environment of informal aptitude is followed.

2. Authors observed that Pakistani companies are doing offshore projects and their clients, which are mostly at remote places, like: USA and UK. Along with this, they are also developing projects for their local clients, which are mostly bespoke projects. Whereas Swedish companies are mostly doing projects for themselves or for their partners and these companies are mostly doing market-driven projects.

3. Authors observed that the overall satisfaction level of requirements validation is higher in Swedish companies in terms of catching defects and cost (see, section 4.10). Whereas Pakistani companies are more satisfied in terms of time/schedule.

4. Authors observed that clients hesitate to sign off the requirements document and do not want to take the ownership of the requirements validation. Sometimes, representatives from the client side do not take the responsibility to sign the review documents. They may be thinking about their job status in case of any problem or due to future change or something else.

5. The Swedish companies, in which authors conducted interviews, are mostly using ad-hoc based reading technique for reviewing their requirements documents. These companies are mostly expert in domains (see, section 4.1) as well. As literature ([25]) suggests that the defect detection in ad-hoc based reading technique is depending upon the knowledge and experience of the reviewer or inspectors. While on the other hand, the companies in Pakistan, in which we conducted interview studies, are mostly using checklist base reading techniques. As literature ([42]) suggests, the check-list based reading technique is structured and considered to be more supportive to the reviewers as compared to the ad-hoc based reading technique.

   Authors observed that the check-list based reading techniques are mostly used in industry (see, section 4.3.4), which are too general and lengthy. These are required to be more specific, customized, precise and up to date, according to the given

scenarios of the requirements documents. This will take some time to create check-lists for the requirements to be reviewed before the time of the actual review meeting. In this way, through checklist based reading techniques, companies can detect more defects during the review meetings in an effective way.

6. Evolutionary and throwaway (described in, section 2.3) are two names of the prototyping, all the companies, in which authors have conducted interviews in Sweden, are using throwaway prototyping (see, section 4.4.1) for validating the requirements. Authors have observed that these companies are using throwaway prototyping due to their product criteria. These companies are developing products on large scale level, so they do not need to use evolutionary type of prototyping instead they just need to validate their requirements and then throw the prototype away. As a result all the development effort for developing the prototyping goes in vain. But if we consider the overall situation, as they are developing products on large scale, so there is no room for errors at the requirements level. So, these companies make sure that they have got the correct, complete and consistent requirements for their products. Authors can say that going into big picture of the overall product, they have saved a lot of developments efforts, cost and time as well.

   While on the other hand, most of the Pakistani companies, where authors have conducted interview studies, are using both throwaway and evolutionary types of prototyping for validating their requirements. During the interviews, we observed that most of the companies are doing offshore developments. For example: sometime their clients are sitting in UK and USA, and some of the times, other system stakeholders are working form other remote locations. So, these companies consider both throwaway and evolutionary types of prototyping, which are most suitable for validating their requirements in this situation. Throwaway prototyping are used and discarded, while add on functionality is appended to evolutionary type of prototyping, which is completed when project is finished.

7. Authors observed that software companies in Sweden and Pakistan are giving their 5 -10 percent of total project time to requirements validation. Companies in Pakistan (see, section 4.8) are spending more time on requirement validation as compare to the Swedish companies. The reason for spending more time in requirements validation in Pakistani companies is that, they are mostly doing bespoke projects and customers in Pakistani companies are unaware of their requirements. And due to the unawareness it is difficult to validate which make requirements validation time consuming activity.

8. Authors observed that most of the Pakistani companies are selecting their RVTs on the basis of their processes. But in Swedish companies RVTs are selected on the basis of suitable scenarios. Along with this, Swedish companies have some sort of relations with academia whereas Pakistani companies have minimal relations with academia.

6. VALIDITY

Summary

Validity of qualitative research is seen as strength to suggest whether the findings are accurate from participant's point of view. The validity of the interview results, used in this thesis study can be assessed. The criteria consist of four different validity assessments for judging qualitative research approaches, which are: credibility, transferability, dependability, and confirm-ability. The validity of the study suggests that interview results included in this report should be credible or believable, from participant's perspective involved in this qualitative research. Transferability is concerned with the ability to generalize the results. Dependability emphasizes on the ever-changing context within which research occurs. Many strategies used to enhance the confirm-ability of this thesis report.

VALIDATION

Validation of research is essential, whether it is quantitative or qualitative [43]. This thesis work is mostly done with the help of qualitative research approach along with quantitative strategies. According to creswell [15], validity of qualitative research is seen as strength to suggest whether the findings are accurate from participant's point of view. The validity of the interview results, used in this report can be assessed according to criteria given by trochim [43]. The criteria consist of four different validity assessments for judging qualitative research approaches, which are:

6.1 Credibility
6.2 Transferability
6.3 Dependability
6.4 Confirm-ability

6.1 CREDIBILITY

As Trochim [41] suggested, the interview results of this thesis report should be credible or believable from the perspective of the participant involved in this qualitative research. To achieve credibility of the thesis report, authors plan a multi-phased research approach including qualitative research along with quantitative strategies. In the first phase, a short literature survey is done, to find out commonly known requirements validation techniques (RVTs) presented in academia. An interview questionnaire (as described in Section 3.4) is prepared, to conduct interviews for getting information about RVTs practiced in software industry.

six companies of two countries (Sweden and Pakistan) are selected (according to the procedures discussed in section 3.5) to conduct interviews regarding RVTs. Legitimate participants (as described in Section 3.3) from selected companies are contacted for conducting interviews. To decide interview meetings with all the subjects, on their available date and time, a proper correspondence (as discussed in Section 3.6) through email taken place before conducting interview meetings. For getting credible information, face-to-face and telephonic interviews (see Section 3.7) are conducted to get believable information. After pursuing this validation process, authors are confident about the credibility of the study.

6.2 TRANSFERABILITY

Transferability is concerned with the ability to generalize the results, for example: in this thesis report, the results of interviews are very helpful to identify the appropriate requirements validation techniques (RVTs) practiced in software industry. This thesis report can be very supportive for software organizations to improve their requirements validation processes by giving information about suitable RVTs according to their project needs. The context of thesis report is described in detail. According to authors' personal experience and interview results; the issues identified in this thesis report and suitable RVTs is a step towards removing these issues.

One possible threat can be related to the subjects involved in the interview process. Even though they all are working at the same level of project managers having three at least years of experience, but their experience in particular domain may have an effect on the results. For example: company A is specialized in service industry, company B has its name in real estate and finance, and company C is working with business and government sector so on so forth. So, all three Project managers of their respective organizations may have their own

background, experience and knowledge, which can be different. But here, authors have tried to use subjects having same level of criteria (as discussed in Section 3.3), for minimizing this threat.

Another possible threat can be educational system and cultural background of the subjects. In this interview study the subjects belongs from two different countries, it is possible that their cultural and educational background is different, which may have an effect on the findings of the study. The environment of natural settings helps to generalize the findings of the study by conducting face-to-face and telephonic interviews.

6.3 DEPENDABILITY

Dependability emphasizes on "the ever-changing context within which research occurs" [43]. The Authors contacted subjects/participants through emails for taking time for the interviews. Some of the people were busy with their already schedules deadlines and they gave time to authors for interview after one and sometimes after two months. Before going to visit the subjects for interviews, authors send a general overview of the topic for which interview was going to be held. Authors did not send the questionnaire before the interview. Authors used environment of natural settings for conducting interviews by visiting subject's office or place on already scheduled date and time. Sometimes authors conduct telephonic interviews.

Sometimes during the interview, authors realized that subject did not know the academic names and terminologies of the activities and processes but they are working with those activities and processes. So, authors ask questions in such a way that subjects describe their whole processes and activities from which required information can be extracted. Sometimes authors conducted more than one interviews in the same organization to find out the exact and relevant answers.

Authors have tried to select same level of companies to generalize the results. All three companies in Sweden, in which authors have conducted interviews, are the top companies, according to their projects and market segment. There is a threat to the validity that some of the companies in Pakistan, in which authors have conducted interview studies, are having different domains and not of the same level of Swedish companies. There is another threat to validity that Swedish companies are doing market-driven projects, while on the other hand companies in Pakistan are doing bespoke projects.

There is another possible validity threat that companies are using different requirements validation techniques. Some companies are using two requirements validation technique and some are three or four. Difference in number of companies may also effect on the finding of the study. If all of the companies are using same requirements validation techniques then there will be no validity threat regarding companies.

6.4 CONFIRM-ABILITY

There are number of strategies used to enhance the confirm-ability of this thesis report. For example: semi-structured interviews (see Section 3.2) are conducted, in which open-ended questions asked for getting required information. During the interviews, authors divide the tasks in such a way that one person asked questions from the subject and the other person was dedicated to document the answers of those questions. In case of any confusion in the answers after the interview, authors discussed it themselves, and in case of any misunderstanding, authors asked from the subject through email to validate the answer.

Authors have refined the interview questionnaire (see Section 3.4), to make sure that it will help to stay focus on the topic of RVTs and extract necessary information. During the interviews authors document the interview results in the form of notes. After conducting the interviews, on the very next day, authors coded the answers into Microsoft excel sheets to keep the data safe.

Authors have conducted telephonic interviews with Pakistani companies whereas face-to-face interviews are conducted in Swedish companies. The difference in conducting interview is also a validity threat because telephonic respondents are likely to make fewer efforts in answering interview questions whereas in face to face interviewee is more aware of interview's reaction to their answer than the telephonic respondent and their answers are much more authentic [44]. Authors have overcome this situation by repeating same question in different ways during telephonic interviews.

7. EPILOGUE

1.1 CONCLUSIONS

This thesis provides an interview study of requirements validation techniques (RVTs) practiced in six companies of Sweden and Pakistan.

This thesis identifies RVTs like, pre-reviews, reviews, inspection, prototyping, testing-based, model-based and viewpoint-oriented requirements validation techniques, which are presented in academia. The data and information of interview results related to specific RVTs is presented in the form of tables and graphs.

The interview studies identify RVTs, which are practiced in industry, for example reviews, prototyping, testing based and model-based RVTs. The pros and cons of each of the RVTs are discussed and analyzed in this report. The comparison of different RVTs is part of the report as well. Prototyping and testing based RVTs are comparatively catching most of the requirements defects. Testing-based RVT is the most expensive one as compared to other RVTs. Requirements reviews and model based RVTs are the cheapest RVTs; while prototyping and testing based RVTs are most time consuming RVTs as compared to other RVTs.

Requirements reviews and prototyping are most widely practiced techniques in industry, whereas testing based and modelling based RVTs are respectively at second and third level with respect to their usage. This study discusses and analyzes the differences in usage of different RVTs in Pakistani and Swedish companies. Pakistani companies are finding more defects through requirements reviews as compared to Sweden organization, whereas Swedish companies are finding more defects through prototyping as RVTs.

This study provides an overview of perceived problems associated with specific RVTs along with its benefits. The study compares different RVTs on the basis of satisfaction level of specific RVTs in terms of catching defects, time/schedule and cost. The RVTs practiced in industry are differentiated on the basis of their satisfaction level, according to Swedish and Pakistani organizations. Most of the Pakistani industries are doing offshore development, while companies in Sweden are doing in-house development.

1.2 FUTURE WORK

This thesis concentrates specifically on requirements validation techniques; further research in this area may be more beneficial. Followings are the areas where future work for requirements validation techniques can be done:

This thesis comprises the study of six companies from two countries (Sweden and Pakistan). It might be interesting and beneficial for further research in the area of requirements validation techniques, to conduct interview studies in the same area from other geographical locations with extended number of companies.

This study is conducted while focusing on senior personnel working in this area, like: project managers, quality assurance managers and software engineers. But it might be more beneficial to involve other stakeholders of the system like, software developers, testers and customers of the developing product as well.

The interviews study conducted in different organizations is not specifically categorized according to the complexity and project size of different companies. It might be interesting and beneficial for further research in this area of RVTs to conduct interviews studies in different companies while focusing on these factors as well.

Requirements are continuously changing in agile development methodologies. As this study was not focused on agile development methodologies; it would be very interesting for future research to investigate suitable RVTs for agile development approaches. It might be interesting for researchers to specify a mechanism that helps to validate the requirements in continuously changing environment.

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APPENDIX 1

Semi-Structured Interview Questionnaire

2. Do you use requirements validation techniques?

3. Which requirements validation techniques do you use for your projects?

a. Requirements Reviews

i. Who is involved in reviewing the requirements?
ii. What are the activities involved in requirements reviews?
iii. Can you give two pros and two cons of requirements reviews?
iv. Do you conduct inspection (formal reviews) as requirements validation technique?
If yes:
a. Do you use any specific inspection technique for requirements validation?
v. Are you satisfied from requirements review as validation technique in terms of:

1. Catching Defects Bad ----1|----2|----3|----4| Very Good
2. Time / Schedule Bad ----1|----2|----3|----4| Very Good
3. Cost Highest ----1|----2|----3|----4| Lowest

vi. Do you think that there is any room for improvement in requirements review practice? If yes then what?
vii. Do you use some specific reading techniques for reviewing or inspecting the requirements documents?
viii. How much time requirements reviews take in accordance with total requirements validation time?

b. Requirements Prototyping

i. What kind of prototyping technique do you use for requirements validation?
ii. What are the activities involved in prototyping for validating the requirements?
iii. Can you give two pros and two cons of prototyping as requirements validation practice?
iv. Are you satisfied from prototyping as requirements validation technique in terms of:

1. Catching Defects Bad ----1|----2|----3|----4| Very Good
2. Time / Schedule Bad ----1|----2|----3|----4| Very Good
3. Cost Highest ----1|----2|----3|----4| Lowest

v. Do you think that there is any room for improvement in prototyping used as RVT?
vi. How much time prototyping takes in accordance with total requirements validation time?

c. Model based requirements validation

i. What kinds of model do you use for requirements validation?
ii. What are the activities involved in model based requirements validation practice?
iii. Can you give two pros and two cons of model based requirements validation technique?
iv. Are you satisfied from model-based RVT in terms of:

1. Catching Defects Bad ----1|----2|----3|----4| Very Good
2. Time / Schedule Bad ----1|----2|----3|----4| Very Good
3. Cost Highest ----1|----2|----3|----4| Lowest

v. Do you think that there is any room for improvement in model based RVT?
vi. How much time this requirements validation technique takes in accordance with total requirements validation time?

d. Testing based requirements validation

i. Do you develop a test case for each of the requirements?
ii. What are the activities involved in testing based requirements validation practice?
iii. Can you give two pros and two cons of testing based RVT?
iv. Are you satisfied from testing-based RVT in terms of:

1. Catching Defects Bad ----1|----2|----3|----4| Very Good
2. Time / Schedule Bad ----1|----2|----3|----4| Very Good
3. Cost Highest ----1|----2|----3|----4| Lowest

v. Do you think that there is any room for improvement in testing based RVT?
vi. How much time testing based requirements validation takes in accordance with total requirements validation time?
vii. Who uses test cases developed at requirements validation phase?

e. Viewpoint-point oriented requirements validation

i. Do you use view-point oriented RVT?
ii. What are the activities involved in viewpoint-oriented RVT?
iii. Can you give two pros and two cons of viewpoint-oriented RVT?
iv. Are you satisfied from viewpoint oriented RVT in terms of:

1. Catching Defects Bad ----1|----2|----3|----4| Very Good
2. Time / Schedule Bad ----1|----2|----3|----4| Very Good
3. Cost Highest ----1|----2|----3|----4| Lowest

v. Do you think that there is any room for improvement in viewpoint oriented RVT?
vi. How much time viewpoint oriented RVT takes in accordance with total requirements validation time?

f. Others, (please specify)

4. How much time requirements validation takes in accordance with the total time of the software project?

5. Can you grade your overall satisfaction level related to RVTs in terms of :
    1. Catching Defects Bad ----1|----2|----3|----4| Very Good

2. Time / Schedule Bad ----1|----2|----3|----4| Very Good
3. Cost Highest ----1|----2|----3|----4| Lowest

6. What are reasons behind selecting these requirements validation techniques:
   - **a.** These are your favorite techniques
   - **b.** These are the only techniques you know
   - **c.** These techniques are more suitable in your particular scenario
   - **d.** others