“Validating the Effectiveness of Communication Model in G.S.D”

A Controlled Experiment

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Declaration

I hereby declare that this Thesis ***"Validating the Effectiveness of Communication Model in G.S.D" A Controlled Experiment*** neither as a whole nor as a part has been copied out from any source. It is further declared that I have done this research with the accompanied report entirely on the basis of my personal efforts, under the proficient guidance of my teachers especially my supervisor *Dr. Naveed Ikram* and Co-supervisor *Ms. Salma Imtiaz.* If any part of the system is proved to be copied out from any source or found to be reproduction of any project from any of the training institute or educational institutions, I shall stand by the consequences.

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In the name of Allah, the most Beneficent and the most Merciful. First of all I am grateful to Allah Almighty the most Beneficent and the source of all Knowledge, for granting me the courage and knowledge to complete this work. Without the blessings of Allah, I would not be able to complete my work.

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In the end I would like to thank all my family members for all the help I needed during this thesis and bear with me all my abnormal routines and timings to complete this thesis.

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Abstract

In Global Software Development software development teams are physically located at different places. This can cause a considerable communication and coordination issues in performing different activities of software development. Requirement validation is the most important part and ever-present activity of Software Development Lifecycle. And software success is highly dependent on this phase. With geographically distributed cites there comes a lot of problems as well and communication and coordination is the mother of all problems. In this research firstly all the quality attributes for validating the requirements are studied and a metric is defined, then a laboratory experiment is chosen as the most appropriate methodology for investigating the effectiveness of the proposed model. Prototyping is taken as a competent and effectual way to comprehend and authenticate system requirements at the beginning of the software development. Then in the end of research the analysis, discussion and the conclusion authenticate the results of the experiment and also present certain enhancements which open further areas for future work of the research.

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1. Introduction

In the past few decades globalization of business has witnessed an increasing trend. This trend has also affected the software industry and has generated a new terminology which is Global Software Development.

Global software development (GSD) means that "the software development is scattered along several sites that are located in different countries and even different continents." (Herbsleb, J.D.; Moitra, D, 2001). As "part of the globalization efforts currently pervading society, software project teams have also become geographically dispersed on a worldwide scale." (Herbsleb, James D, 2007). "GSD has many known and unknown benefits like improved resource allocation, team benefits, such as reduced coordination cost and improved team autonomy, and process benefits, such as improved documentation and clearly defined processes." (J. Ågerfalk1, Fitzgerald1, Holmström Olsson1, and Eoin Ó Conchúir1, 2008). On the same hand globally distributed projects also suffer from communication and coordination problems as the team members are physically separated, frequency of communication between them drops off sharply (Herbsleb, James D, 2007), (Sengupta, Chandra, Sinha, 2006).

Requirement engineering is one of the most crucial activities of software development. Software development in global environments has a profound effect on Requirements Engineering (RE) activities. It is highly interactive and the communication and collaboration between various stakeholders determines the quality of the final product (Jane Coughlan, Robert D. Macredie, 2002).

They also describe a set of sub-processes involved in requirements engineering phase. These are requirements elicitation, requirements specification and requirements validation. These processes cannot be isolated; their relationship is depicted in the figure below.

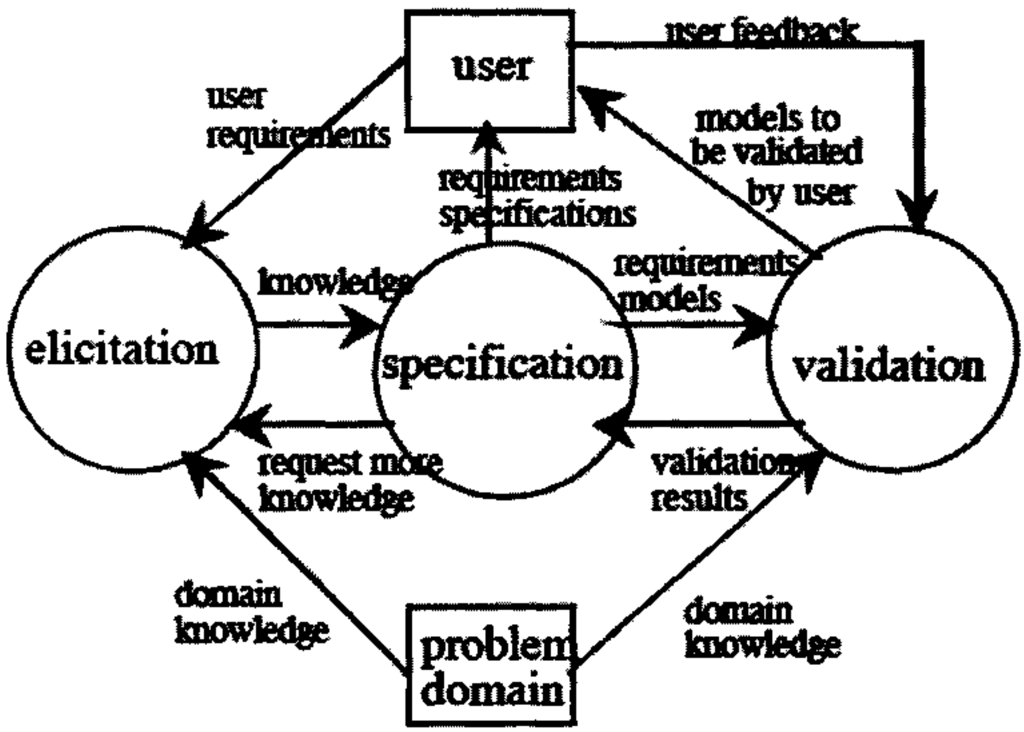
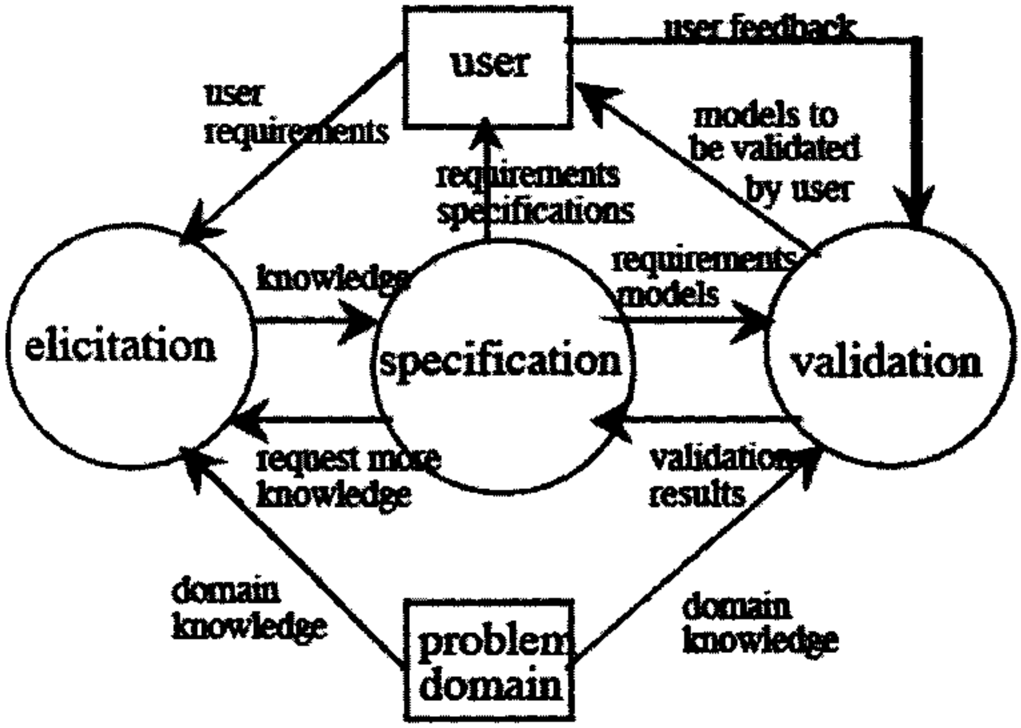


Figure1.1. Requirement Engineering Process

Requirement Validation is the most important part and ever-present activity of the Software Development Life Cycle (SDLC). Software success is highly dependent on this phase. During validation direct involvement of stakeholders is usually required in reviewing the requirements artifacts (B.H.C. Cheng and J. M. Atlee, 2007). So R.V requires a lot of communication and coordination among the stake holders otherwise cost of fixing requirements errors later in software development is very high. Requirement validation is useful in reducing these requirement costs by detecting these errors early. As quoted "Fixing a requirements error after delivery may cost up to 100 times the cost of fixing an implementation error", (Sawyer, Sommerville, and Viller, 1999) so it is very important to make early requirements validation.

R.V is defined as:

"Am I building the right product?"(Fleisch, 1999).



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R.V is defined as:

"Am I building the right product?"(Fleisch, 1999).

In literature it is studied that R.V is done through these quality attributes, Correctness, Completeness, Un ambiguity, Consistency and According to user's need.(Sawyer, Sommerville, and Viller, 1999), (Katasonov Markku Sakkinen, 2005), (Wolfgang Fleisch, 1999), (Julio Cesar Sampaio do Prado Leite, 2002),(Westfall, 2006). About "40-60% of all defects found in a system can be traced back to incomplete, inconsistent or ambiguous requirements." (Sukumaran, Sreenivas, Venkatesh, 2006), (Loucopoulos, P. and Karakostas, 1995). Various activities are performed in the process to ensure correctness, consistency, non-ambiguity and feasibility of requirements. (Loucopoulos, P. and Karakostas, V. (eds), 1995)

Requirements validation activities are performed to ensure the following desired properties:

• **Correctness:** "Each requirement must accurately describe the functionality to be delivered." (Karl E. Wiegers, 1999). "The formalized requirements should reflect user intentions accurately, resulting in software system that behaves as expected." (Sukumaran, Sreenivas, Venkatesh, 2006).

• **Consistency:** There should be no internal contradictions in the requirements feature list and requirements and information provided by the system or to the system do not contradict with each other (Sukumaran, Sreenivas, Venkatesh, 2006), (Loucopoulos, P. and Karakostas, 1995), (Sommerville, 2004).

• **Completeness:** It should be ensured that the requirements model does not omit any essential information about the problem domain. (Sukumaran, Sreenivas, Venkatesh, 2006), (Sommerville, 2004). "No requirements or necessary information should be missing. Completeness is also a desired characteristic of an individual requirement." (Karl E. Wiegers, 1999).

• **Non-ambiguity:** Requirements should be clear in the sense that they cannot be interpreted in more than one way (Loucopoulos, P. and Karakostas, 1995). Also "the reader of a requirement statement should be able to draw only one interpretation of it." (Karl E. Wiegers, 1999).

There are various techniques for RV. The widely employed techniques for validation are: (Loucopoulos, P. and Karakostas, 1995), (Budde, Ziillighoven, 1990), (Andriole, S.J. 1994), (Gemino, A., 2004), (Tyran, George 2002), (Ciolkowski, Laitenberger, Biffl, 2003), (V. Ambriola, V. Gervasi, 1997)

- Prototyping
- Animations
- Inspections
- Natural Language

1.1 Background and Motivation:

Research (A. Munir and N. Ikram, 2009) has highlighted the problems of communication and coordination in GSD environment and has proposed a model to solve these problems.

The aim of the research conducted by Asma (A. Munir and N. Ikram, 2009) was to understand the communication and coordination problems encountered when requirements validation techniques for traditional software development are employed in GSD context and suggest a possible solution. Following are the questions that were addressed by the above mentioned research (A. Munir and N. Ikram, 2009):

- *"How effective are traditional Requirements Validation techniques, with respect to communication and coordination, when applied in a globally distributed software development environment"?*

- *"What possible measures can be taken to improve the effectiveness of these techniques in GSD with respect to communication and coordination"?*

The author has proposed a communication model to address the communication and coordination issues that exacerbate the problems of requirements validation through prototyping in GSD. This model is shown in the figure 1 below:

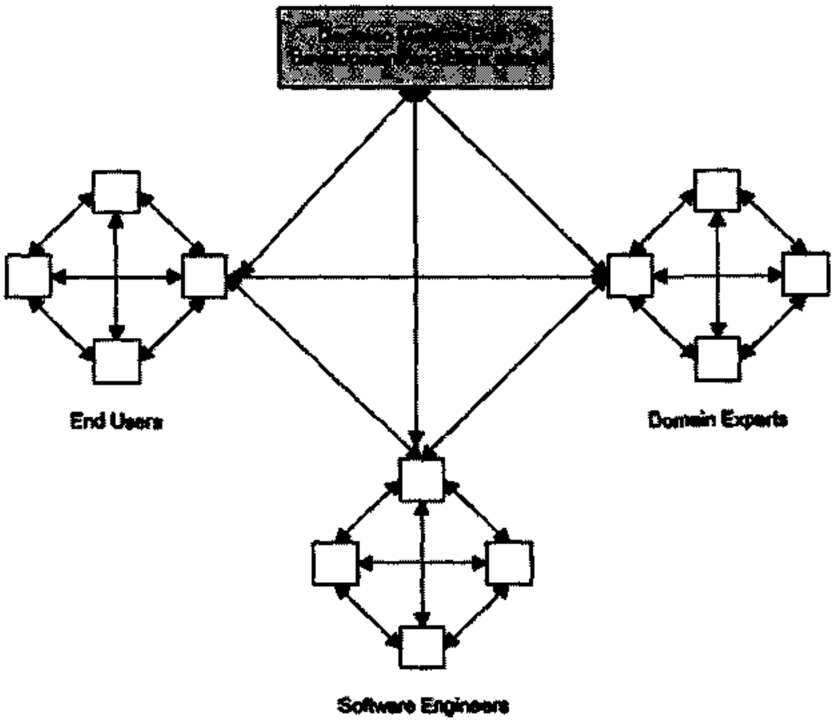


Figure1.2. Communication and coordination model

The model is characterized by communication between various stakeholder roles through a lead role, which communicates with the general domain roles, filters information and relays it to the other stakeholder groups. The decision makers, managers from both the client and development side, need to spread the general awareness among the team members regarding importance of establishing these roles and enable communication between them for an overall successful project. Clear definition of these roles and their responsibilities will facilitate initiation of contact and continued communication over project information.

- This model stresses on fewer communication links so as to avoid miscommunication attributed to multiple conflicting opinions being transferred to other roles.
- Furthermore, by establishing communication links only with the representatives or lead-roles, difficulty of communication between large numbers of individuals across time zone differences is comparatively reduced.

Different types of stake holders are:

1. *End-users:* "The actual users of the system."

2. *Domain experts:* "Experts in a particular aspect of the problem or solution domain."

3. *Developers:* "Designers, coders, technical writers, testers, and any other types of developer involved in the production and support of the system."

4. *Decision-makers/Managers:* "The business managers, financiers, department heads, sellers, marketers, and other people who are investing in the production of the system."

These stakeholders are only indirect users of the system or are affected only by the business outcomes that the system influences.

1.2 Limitations of the previous research

The problem in that research was the limited validation of the proposed communication model. It was a case study performed on an already finished project. The project started in 2002 and finished in 2005 whereas the author did this case study in 2009. The author did not implement the proposed model on the case; rather reasoning was used to show the effectiveness of the communication model on the case chosen.

The reasoning was based upon the data obtained from the survey done by the author at the end of the case study; the survey involved the stakeholders of that project.

Moreover the author did not provide what kinds of questions were asked in the interview.

1.3 Contribution and Research methodology

A laboratory experiment is selected as the most suitable methodology for validating the authenticity and accuracy of the research questions and hypothesis. Experiments provide a high level of internal and external validity and are widely used to evaluate models. "If a high level control over the variables is possible that can affect the truth of hypothesis then an experiment can be conducted." (John Wiley & Sons Ltd., 2002). We are using experiment as a research methodology because experiments can confirm or refute the accuracy and dependability of the proposed models and their generality by comparing the predictions with the actual values in a carefully controlled environment. (Fleeger, 1995) For this a real world project has been chosen and is developed in a controlled environment; the students from two different universities from two different countries were involved in this experiment.

1.4 Experimental Design:

The brief experiment design is given below:

1.4.1 Hypothesis:

There is a relationship between requirements validation and the Communication and Coordination Model.

1.4.2 Null Hypothesis:

There is no significant difference between the requirements validated with or without using communication and coordination model.

For conducting this experiment cross over design was used which is shown in the table below:

Table 1.1: Cross Over Design Table

Treatments/ Tool		Module 1	Module 2
1.	With Model	A= a group of 9 members	B= a group of 9 members
		Survey Questionnaires	Survey Questionnaires
2.	Without Model	B	A
		Survey Questionnaires	Survey Questionnaires

In 1st treatment group A will work with model and will perform R.V and group B will work without model and in 2nd treatment group B will work with model and group A will work without model for Requirement Validation and a survey questionnaire will be filled by the participants in the end of every treatment.

1.4.3 Experiment objects:

The requirement validation form will act as an experiment object.

1.4.4 Experiment subjects:

Students of undergrad level will be the subjects to perform this experiment.

1.4.5 Independent Variables:

The Communication and Coordination model by (A. Munir and N. Ikram, 2009) will be independent variable during Requirements Validation.

1.4.6 Dependent Variables:

The feature list's correctness, un-ambiguity, completeness, consistency and customer's satisfaction are the dependent variables.

1.4.7 Measurement Tools:

The questionnaires will be designed to collect information on the participant's attitude towards the effectiveness of the model and will act as measurement tool.

1.4.8 Instrument Design:

A form is designed which will be used to determine the improvement in communication and coordination and different quality attributes for requirement validation are used to get feedback on the requirements.

We will be using bipolar rating scale i.e. Likert scale to determine the requirement validation process with five points scale. The format of a five level likert item is;

1) Strongly agree
2) Agree
3) Disagree

4) Strongly disagree
5) Neutral

Along with this some open ended questions will also be asked to find the views of the participants on the experiment and model. Moreover some questions will also be asked to judge whether the teams (clients and developers) are new to each other or already have worked together so that level of understanding and communication and coordination can be judged.

1.5 Limitations

The participants of the experiment will be the students of undergrad level with almost same level of understanding but they are not the professionals.

The Peer Review of the questionnaire will be done to check whether there is any need of improvement in instrument. The questionnaire will be circulated among the members of the MSSE/P.H.D students as a peer review process.

1.6 Data Recording and Analysis Strategy

After the execution of questionnaire the data will be recorded into tables.

We will record the opinion of the users about the requirements in the form adapted from (Yu-Ting, Liu, Shwu-Jiuan Wu, Ting- I Lee, 2008), (Offutt, Ye Wu, Xiaochen Du and Huang, 2004) and modify it according to the criteria, furthermore questions from Karl Weigers "Requirement Verification Checklist" are modified according to Requirement Validation criteria, which we studied from literature, for good requirement validation.

Then for analysis different statistical test will be applied e.g. chi-square test, average and percentage analysis.

1.7 Thesis Outline

The remaining document is structured as:

Chapter 2: It reviews the relevant literature pertaining to Global Software Development, Requirement Engineering in G.S.D and then the Requirement validation in G.S.D. This study underlines the significance of this research area, also the quality attributes are also studied to measure the Requirement Validation process in G.S.D. environment.

Chapter 3: This chapter discusses the whole research methodology i.e. controlled experiment, its design in detail and the steps carried out to conduct this experiment. Moreover it also discusses that how data is collected from the experiment.

Chapter 4: The fourth chapter comprises of data analysis that is how the whole data was being collected and analyzed. The tests used for data analysis. Plus it also discusses that what results are found after all the data analysis.

Chapter 5: It sheds light on the main contribution of the whole research work done, its achievements and the proposed future work.

2. Literature Review

In this chapter we have discussed GSD, RE in GSD, what are the requirements validation techniques, what are the quality requirements validation attributes and how requirement validation is done.

2.1 Global Software Development

Global Software Development has become a need for business for its extensive benefits. Big organizations successfully use this to capitalize on global resources and get maximum advantages from them. "As a result, software development is increasingly a multisite, multicultural, globally distributed undertaking." (Herbsleb, Moitra, 2001)

GSD has its own benefits and challenges. "Numerous pressures have converged to vastly increase the extent of multi-site and outsourced software development projects." (Arora, Gambardella, 2004). But despite its extensive benefits it has many issues that need to address in detail and any solution should be given for them. Like Communication and Coordination issues which increases ambiguities, misunderstandings etc as discussed in (A. Munir and N. Ikram, 2009)

Engineers, supervisors, executives, and managers encounter frequent, alarming challenges on many levels, from the technical to the social and cultural. (Arora, Gambardella, 2004) and due to the large distance among these stakeholders communication and coordination issues arise.

2.2 Requirement Engineering in GSD

Software requirements engineering is the process of determining what is to be produced in a software system. Requirement Engineering is an important part of the Software Engineering, as said by (Oberg, R., Probasco, L., and Ericsson, 2000). "A requirement is the condition or capacity that a system that is being developed must satisfy, when considering RE during global software development." (Damian and Zowghi, 2003) state "inadequate

communication in global structures creates most challenges" and adds many fundamental problems. It is also suggested there that unless the four major aspects of cultural diversity, inadequate communication, knowledge management and time differences, are addressed in global software development, the stakeholders will face difficulties in RE practice.
The process framework for GSD is

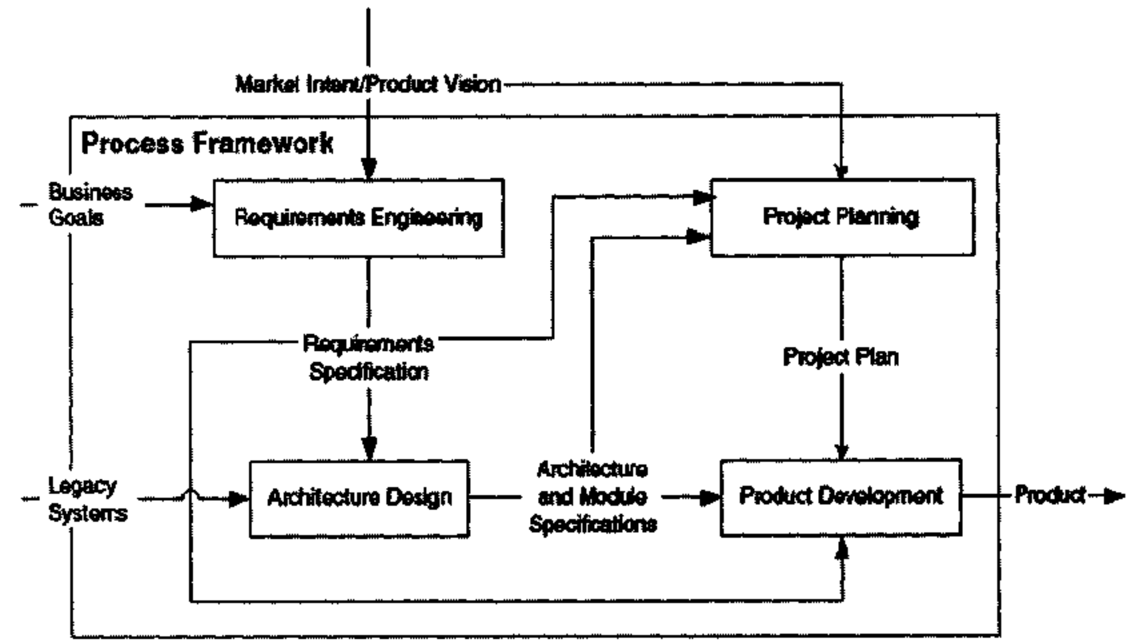


Figure2.1. Process Framework for G.S.D.

It is clear from the figure that RE is the far most important part of the GSD framework. If the quality of the software requirements is better, then it cannot only result in a considerable improvement of the excellence of the requirement engineering phase but also of the whole software which is being developed. In other words, "RE if not carried in an efficient way has a profound effect on other phases of software development i.e. design, implementation, testing and maintenance." (Cheng and Atlee, 2007), (Loucopoulos, and V. Karakostas, 1995). However, requirement engineering job is not simple and is acknowledged to be very compound. (Anton, Potts, 1998) as was stated by (F.P.Brooks, 1987) in his seminal paper "No Silver Bullets": *"The hardest single part of building a software system is deciding what to build. ... No other part of the work so cripples the resulting system if done wrong. No* *other part is more difficult to rectify later".* Hence, "there is a strong consensus in the software research community about the importance and challenges related to requirement engineering which render this field a very important status in software/system engineering." (Sommerville, Ransom, 2005), (Anton, Potts, 1998).

Although RE process is considered as highly intertwined with other organizational processes (Damian and Chisan, 2006), however there exists a very well defined set of activities that constitute the RE process (Loucopoulos, and V. Karakostas, 1995), (Jiang, 2008), (Wiegers, 1999), (Sommerville, Sawyer, 1998), (Sommerville and G. Kotonya, 1998). Hence, it is important to list down the requirement engineering activities that make up the substance of the RE phase.

The main RE practices are mention in the figure below:

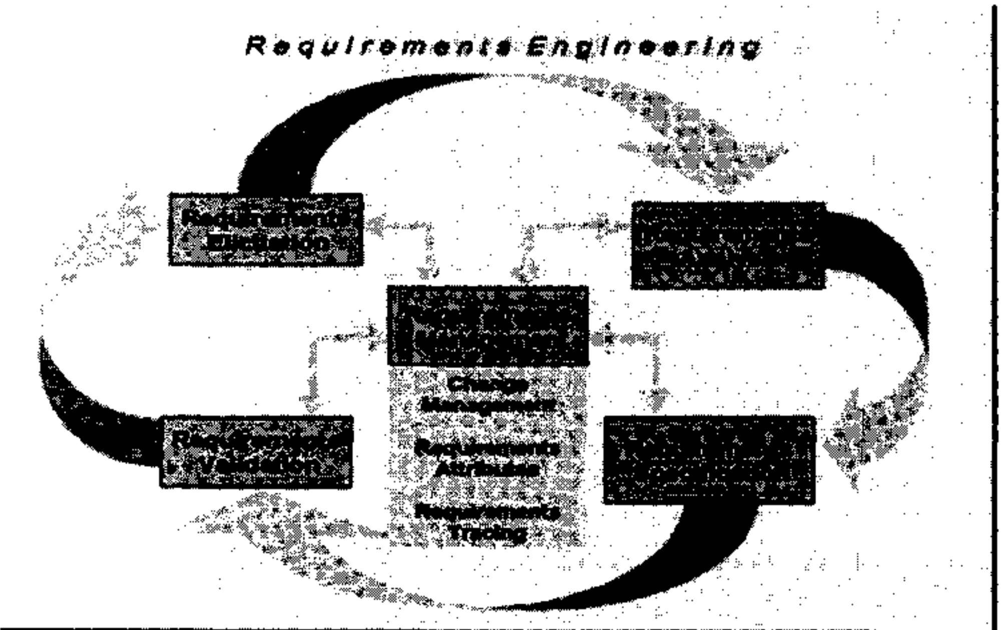


Figure2.2. Requirement Engineering Practices

Requirements Elicitation

"Elicitation refers to gathering the requirements of the system from different stakeholders.

Requirements elicitation comprises activities that enable the understanding of the information, which is collected from the stakeholders."

Requirements Analysis

"After elicitation of requirements, requirements are subjected to analysis in order to remove errors in requirements and check inconsistent, incomplete and conflicting requirements." (Cheng and Atlee, 2007).

Requirements Specification

"Requirements specification is a structured document, which sets out the system services in detail. It includes all necessary information about what the system must do and all the constraints on its operation. This document may serve as a contract between the system buyer and software developer." (Cheng and Atlee, 2007), (Dieste, Lopez, Moreno, 2001).

Requirements Validation

Requirement Validation is the process of substantiating the clients or the user of the software that the particular requirements are valid, correct, and complete. Requirements validation makes sure that models and documentation precisely articulate the stakeholders' needs. Validation usually requires stakeholders to be directly involved in reviewing the requirements artifacts (Cheng and Atlee, 2007).

Requirements Management

Requirements management is an umbrella activity that encompasses a numerous jobs that are related to the requirements management, it also includes the progression of requirements over the time. "Requirements management also includes analysis that determines the maturity and stability of elicited requirements, so that the requirements most likely to change can be isolated." (Cheng and Atlee, 2007), (Bush and Finkelstein, 2003).

2.3 Requirement Validation in GSD

Requirement Validation process is the most important and ever-present activity during software development. "The requirement validation process ensures that the requirements in software requirements specification are consistent and complete." (Kotonya, Sommerville, 1998).

There are many techniques for requirement validation like:

- Prototyping
- Animations
- Inspections
- Natural Language

In thesis (A. Munir and N. Ikram, 2009) a framework (shown in figure) is presented and through this framework the effectiveness of these RV techniques are studied.

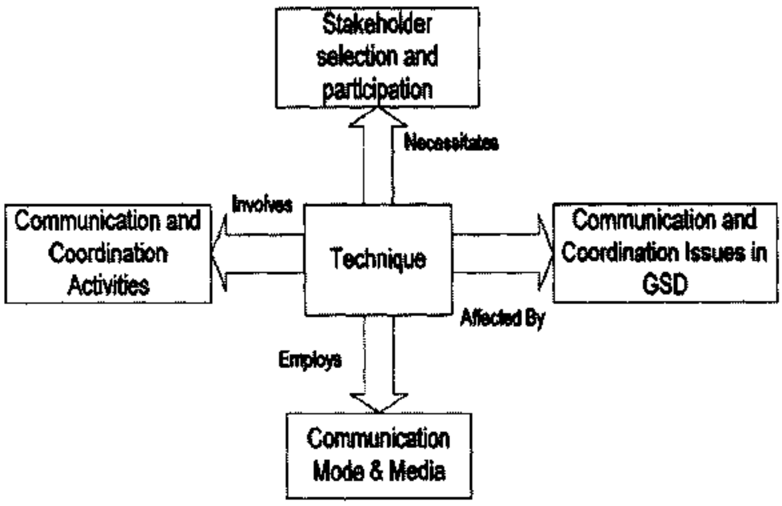


Figure2.3.Framework used to study R.V. techniques

From the comparative evaluation of widely employed requirements validation techniques, it is concluded that prototyping proves to be the best choice for validating requirements in a GSD environment. It works as an interaction medium between the multiple stakeholders thus improving the quality of communication. It requires lesser communication and coordination activities as compared to inspections and NL that necessitate high interaction between the relevant stakeholders. However, it is of highest importance to come up with a suitable solution that deals with the issues and challenges that are faced in this technique in a GSD context so as to make it successful and effectual.

2.4 Requirement validation attributes in literature

From the literature requirement validation attributes are studied like in paper (Wasson, 2004) the traditional measures in requirements quality are discussed and these are "(un)ambiguity, completeness, consistency, correctness, readability, maintainability, testability", etc. "A tentative starter set for the requirements quality measures that might be addressed includes the traditional measures of requirements quality: (un)ambiguity, completeness, comprehensibility, consistency, correctness, implementability, maintainability, modifiability, readability, writability, testability, traceability, etc." (Sawyer, Sommerville, Viller, 1999) defines Requirements validation as "establishing procedures to check for correctness, completeness, consistency, and compatibility. Ensuring that requirements are verifiable and those quality standards are adhered to".

In paper (Fleisch, 1999) Requirement validation is achieved by inspecting the following criteria

- completeness
- consistency
- feasibility
- Testability

within an actual requirements specification and tracing the requirements through the whole development process.

In paper (Cesar Sampaio, Freemen, 1991) the authors through view point checked for the following types of discrepancies:

- Wrong Information
    - contradiction between the facts of the different rule sets

- Missing Information
  - Incomplete hierarchies with respect to rule facts
  - missing rules
  - missing facts
- Inconsistency
  - contradiction between a fact and the hierarchy
  - redundancy in the same rule set.

In paper (Westfall, 2006) according to authors the peer review process should look at the requirements as a whole to ensure that they are:

-Complete	*-Consistent*	*-Modifiable*	*-Unambiguous*	*-Concise*
-Finite	*-Measurable*	*-Feasible*	*-Testable*	*-Traceable*

In another paper (Katasonov, 2005) says "the quality of requirements is usually measured with a set of quality attributes, whether one speaks of verification or validation depends actually on which of the attributes are in question," as is shown in Figure below:

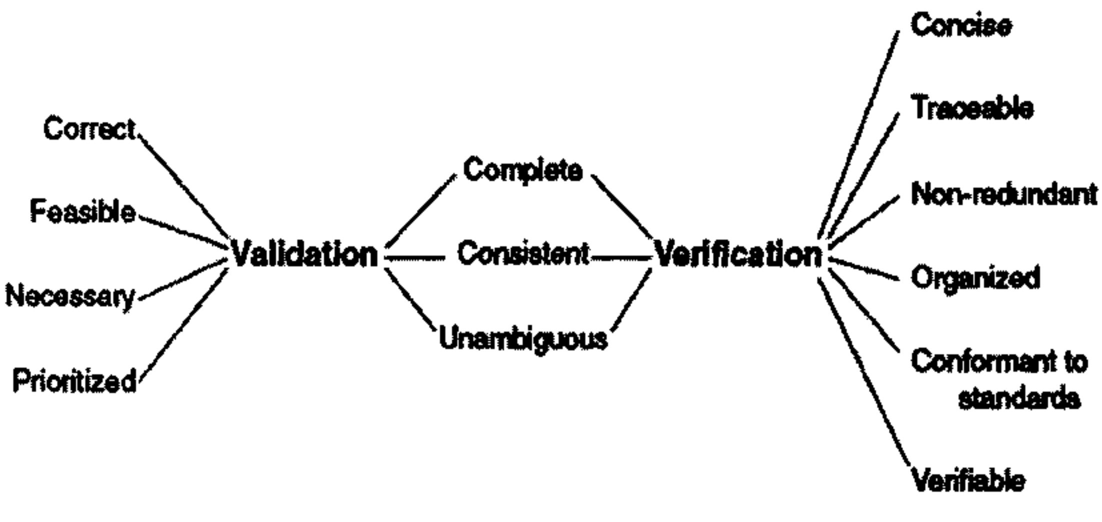


Figure2.4. Quality Requirement attributes for measuring R.V.

2.5 Metric for Quality attributes for Requirement Validation

After all this literature survey these points are concluded:

- Validation is: "Am I building the requirements right?"
- Most papers focused on these attributes that contribute to the quality requirement validation are:
    - Consistency
    - Completeness
    - Correctness
    - Un ambiguity
    - According to users need

2.5.1 Consistency

By consistent we mean that there should be no internal contradictions in the requirements and information provided by the system or to the system.

2.5.2 Completeness

By complete information we mean that any essential information about the problem domain is not omitted. Any requirements or even any necessary information should not be missing. Completeness is also a most wanted attribute of an individual requirement.

2.5.3 Correctness

The represented and desired requirements should reflect user objective and intentions precisely. Correctness in requirements is simply about getting it right. Correctness applies in a context. "Are these the right requirements to achieve any goal X?"

2.5.4 Un-ambiguity

Requirements should be clear in the sense that they cannot be interpreted in more than one way. No conflicts should be generated from such requirements that lead to dual meanings.

2.5.5 According to users need

The system developed should be according to the needs of its users. The MUST requirements should be present in the system.

3. Experiment Design and Execution

In this chapter the thorough experiment design is discussed and how the whole experiment is conducted while having the control on all variables (dependent and independent) that can affect the results of this experiment. Hence the following experimental design was devised.

3.1. Experimental Design:

This is a brief experiment design:

3.1.1. Hypothesis Formulation:

The hypothesis of the research is:

3.1.2. Null Hypothesis:

a. There is no significant difference between the requirements validated using communication model and without communication model.
b. The number of correct requirements does not increase while using a model.
c. The number of complete requirements does not increase while using a model.
d. The number of consistent requirements does not increase while using a model.
e. The number of unambiguous requirements does not increase while using a model.
f. The user satisfaction level is not satisfactory when using a model.

3.1.3. Alternate Hypothesis:

a. The proposed Communication Model improves Requirement Validation in GSD.
b. The number of correct requirements increases while using a model.
c. The number of complete requirements increases while using a model.
d. The number of consistent requirements increases while using a model.
e. The number of unambiguous requirements increases while using a model.
f. The user satisfaction level is achieved while using a model.

3.2. Treatment:

The proposed Communication and Coordination Model by (A. Munir and N. Ikram, 2009).

3.3. Experiment Operation:

We will use an AB/BA crossover design (John Wiley & Sons Ltd., 2002), (Fleeger, 1995). In a crossover study design, the participants are assigned to a sequence of treatments in order to study differences between individual treatments. This is a balanced design in which each experimental unit (i.e. group of 9 members) will perform validation of requirements in GSD environment. A test will be performed after each treatment. The test is a survey that will be conducted on members of group A and B and will be opinion based.

The cross over design is shown in table; 1 below:

Table 3.1: Cross Over Design Table

Treatments/ Tool		With Model	Without Model
1.	Module 1	A= a group of 9 members	B= a group of 9 members
		Survey Questionnaires	Survey Questionnaires
2.	Module 2	B	A
		Survey Questionnaires	Survey Questionnaires

- It is a cross over design.
- In 1st treatment group A worked with model on module 1 and performed R.V and group B worked without model on module 1.
- In 2nd treatment group B worked with model on module 2 and group A worked without model on module 2 for Requirement Validation.
- In order to reduce the biasness in our experiment both groups worked on different modules at one time.

- At the end of every treatment a survey questionnaire was given to the participants of experiment to be filled to gain the data for further analysis.
- Both groups were further divided into 3 subgroups.
- Each will had 3 members.
- One group was of end users, second group was of s/w engineers and third group was of domain experts and each group had one representative.

3.4. Experiment objects:

The requirement validation form will act as an experiment object.

3.5. Experiment subjects:

Students of undergrad level will be the subjects to perform this experiment.

3.6. Independent Variables:

The Communication and Coordination model by (A. Munir and N. Ikram, 2009) will be independent variable during Requirements Validation.

3.7. Dependent Variables:

The feature list's correctness, un-ambiguity, completeness, consistency and customer's satisfaction are the dependent variables.

3.8. Measurement Tools:

The questionnaires will be designed to collect information on the participant's attitude towards the effectiveness of the model and will act as measurement tool.

3.9. Instrument Design:

A form is designed which will be used to determine the improvement in communication and coordination and different quality attributes for requirement validation are used to get feedback on the requirements.

We will be using bipolar rating scale i.e. Likert scale to determine the requirement validation process with five points scale. The format of a five level likert item is;

1- Strongly agree
2- Agree
3- Disagree
4- Strongly disagree
5- Neutral

Along with this some open ended questions will also be asked to find the views of the participants on the experiment and model. Moreover some questions will also be asked to judge whether the teams (clients and developers) are new to each other or already have worked together so that level of understanding and communication and coordination can be judged.

3.10. Limitations:

The participants of the experiment will be the students of undergrad level with almost same level of understanding but they are not the professionals.

The Peer Review of the questionnaire will be done to check whether there is any need of improvement in instrument. The questionnaire will be circulated among the members of the MSSE/P.H.D students as a peer review process.

3.11. Data Recording and Analysis Strategy:

After the execution of questionnaire the data will be recorded into tables.

Then we will record the opinion of the users about the requirements in the form adapted from (Yu-Ting, Liu, Shwu-Jiuan Wu, Ting- I Lee, 2008), (Offutt, Ye Wu, Xiaochen Du and Huang, 2004) and modify it according to the criteria, furthermore questions from Karl Weigers "Requirement Verification Checklist" are modified according to Requirement Validation criteria, which we studied from literature, for good requirement validation.

3.12. Experiment Execution

This explains the whole experiment execution

3.12.1. General Information:

- The students of two universities were selected.
- The students were from bachelor's level and had same knowledge level.
- The students were divided into two main groups A and B.
- Both groups were further subdivided into three sub groups each i.e. developer group, domain expert group and user group. Each group was consisted of three members.
- The domain expert and user group were chosen from University of England and developers were from University of Pakistan.
- Both asynchronous and synchronous modes of communication were used during execution of the experiment.
- The medium of communication was Email in case of asynchronous mode and Instant Messaging and Voice Chat in case of synchronous mode.
- Log of both synchronous and asynchronous communication was saved for further analysis.
- Gmail id's were provided to domain experts, users and the developers to communicate with each other through Email and IM.
- Only the team leads communicated with each other in case of the group which was using communication model while validating the prototype.
- Whereas each member of domain expert, user and developer groups communicated with each other when communication model was not used.

3.12.2. Steps for the Experiment:

These are the treatments of the experiment

Treatment 1: Team A will work with Model on Module 1 and Team B will work without model on Module 1.

Treatment 2: Team A will work without Model on Module 2 and Team B will work with model on Module 2.

3.12.2.1. Explanation of Treatment 1

A brief introduction to the communication and coordination model was given to all the participating students of all teams. There were two briefing sessions held, one for the developers here in Pakistan which was done through F2F meeting and second briefing session was for the users and domain experts in UK and it was done through presentations and voice chats.

In the end of the briefing session the copy of the SRS of the real world project that is REMMF Tool Development was provided to the developers. (The snapshots of the tools are in Appendix B). The developers were then given 2 weeks time period to develop the working prototype of the software. Once the prototype was made it was uploaded on the domain and URL was provided to the end-users back in U.K for the validation of the requirements. And then 1 week time period was given to team A for validating the prototype by using the model and to the team B for validating the prototype without using the model.

During validation time team B worked with model and only the team leads communicated with each other whereas team A worked without model and each member of their teams communicated with each other. This all communication was carried out through chats, e-mails, voice chats and F2F meetings.

After completion of requirement validation step each group member was given a questionnaire to report their experiences about the experiment. And after that an analysis was performed to see the results of the experiment.

3.12.2.2. Explanation of Treatment 2

A brief introduction to the communication and coordination model was given to all the participating students of all teams. There were two briefing sessions held, one for the developers here in Pakistan which was done through F2F meeting and second briefing session was for the users and domain experts in UK and it was done through presentations and voice chats.

In the end of the briefing session the copy of the SRS of the real world project that is REMMF Tool Development was provided to the developers. The developers were then given 1 week time period to develop the working prototype of the software. Once the prototype was made it was uploaded on the domain and URL was provided to the end-users back in U.K for the validation of the requirements. And then 1 week time period was given to team A for validating the prototype by using the model and to the team B for validating the prototype without using the model.

During validation time team A worked with model and only the team leads communicated with each other whereas team B worked without model and each member of their teams communicated with each other. This all communication was carried out through chats, e-mails, voice chats and F2F meetings.

After completion of requirement validation step each group member was given a questionnaire to report their experiences about the experiment. And after that an analysis was performed to see the results of the experiment.

3.13 Challenges while doing an experiment

The data collection procedure was through e-mails, voice chats, chats etc. the analysis of those showed the level of understanding of the students and their compatibility with each other. However some problems were also faced e.g. there was a time zone difference which was a big hurdle as sometimes the students had to wait for other members of the groups for conducting experiment and had to wait for any e-mail response. Moreover although the language was not a very big issue as English is widely used and understood but still sometimes the accent of the students from U.K was difficult to understand for the students here in Pakistan.

3.14 Experiment Validity

Experimental validity was also checked by seeing the internal and external threats.

3.14.1 Threats to Internal Validity

"Threats to internal validity are those factors that may affect the value of the dependent variable apart from the independent variable." (Kitchenman, B.A., et al, 2002) (Toothaker, L.E, Miller, 1996). (Wholin et al., 2002) identify "four main threats to internal validity: selection effects, maturation effects, instrumentation effects, and presentation effects."

These threats are a problem for quasi-experiments, but are irrelevant when a cross over design is used where arbitrary allotment of sequence is planned to avoid these problems. (Senn, S., 2002). Another possible threat is the biasness of the form designed for quality check but it was addressed by peered reviewing the form by the MS students. Furthermore, the biasness of the learning was reduced by working on two different modules of the project for both the treatments. The fatigue effect was reduced as the subjects were given sufficient time to perform the experiment.

3.14.2 Threats to External Validity

Threats to external validity are those that may bind the applicability of the experimental results to industry practices. The experiment considered three threats to external validity: participant representativeness, instrumentation representativeness and process representativeness.

To address these threats the subjects chosen for this experiment are the students of 3rd and 4th year undergraduate students from two different universities. The students were new to each other and did not have any prior experience of working in GSD environment. This seems to be a threat to applicability of results. However, we do not consider it as crucial as many organizations do not have any extensive training of their employees for working in GSD environment. Additionally the students were of same level of understanding. The size of the groups is comparable with other systems used in related experiments.

Chapter 4: Data Analysis and interpretation.

The given study aims to investigate what is the effect of communication and coordination model proposed earlier. This study is going to compare how communication and coordination is being effected with and without the model.

For this purpose two types of analysis were performed quantitative as well as qualitative. The quantitative data was collected through the questionnaire filled by each subject of the experiment. Then this questionnaire was analyzed by applying statistical tests. "Descriptive statistics, such as mean values, standard deviations, histograms and scatter plots, are used to get an understanding of the data that has been collected." (Per Runeson & Martin Höst)

The chi-square test is also used for analyzing this type of data but in our case the data sample was limited and the data is not normally distributed so we cannot apply this test here.

We also cannot perform parametric tests like t-test as we are not finding the induction of one variable on other, both are independent variable, we are just analyzing their co-relation and our data sample was also small so the best suitable test for this situation is Mann-Whitney U-Test.

The qualitative analysis was performed on the data collected through a separate open ended questionnaire filled by the same subjects. The basic objective of this type of analysis was to derive conclusions from the data, keeping a clear chain of evidences.

For the analysis a likert scale was used having options as Strongly Agree (SA), Agree (A), Disagree (DA), Strongly Disagree (SDA) and Neutral (N) and each of them is numbered with codes 5,4,3,2,1 respectively.

4.1 Quantitative Analysis:

Quantitative analysis is an analysis technique that intends to comprehend the performance through the use of multifaceted mathematical and statistical modeling, measurement, and research. The main aim of assigning a numerical value to variables by the quantitative analysts is to reflect reality in mathematical terms. Quantitative analysis can be performed for various reasons like performance evaluation, measurement, or evaluation. The questionnaire collected the quantitative subjective data using closed questions with five point likert scale.

4.1.1 Mann Whitney Test

The logic behind the Mann-Whitney test is to rank the data for each condition, and then see how different the two rank totals are. If there is a systematic difference between the two conditions, then most of the high ranks will belong to one condition and most of the low ranks will belong to the other one. As a result, the rank totals will be quite different. On the other hand, if the two conditions are similar, then high and low ranks will be distributed evenly between the two conditions and the rank totals will be fairly similar. The Mann-Whitney test statistic "U" reflects the difference between the two rank totals. Thus it is the best test to compare mean scores when the dependent variable is not normally distributed and at least of ordinal scale.

4.1.1.1 Correct:

The formalized requirements should reflect user intentions accurately. Correctness in requirements is simply about getting it right. Correctness applies in a context. "Are these the right requirements to achieve any goal X?" Mann-Whitney U test was used for interpreting all questions.

Statement: 4.1.1.1.a Does the prototype provide the required information?

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Mean Rank tells about the mean rank of the treatments whereas Sum of Ranks shows the total rank of the each treatment from which we can clearly see that there is a great difference between the two treatments.

Table 4.1.1.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
	1	18	11.67	210.00
Response	2	18	25.33	456.00
	Total	36		

The Mann-Whitney U value is 39 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.1.1.b Test Statistics

	Response
Mann-Whitney U	39.000
Wilcoxon W	210.000
Z	-4.183
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

Statement: 4.1.11.b The response time to your input was satisfactory.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 221.50 in case of treatment 1 and 481.15 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.1.2.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Response	1	18	11.66	221.50
	2	18	26.75	481.50
	Total	36		

The Mann-Whitney U value is 31.5 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.1.2.b Test Statistics

	Response
Mann-Whitney U	31.500
Wilcoxon W	221.500
Z	-4.431
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

4.1.1.2 Consistency

Being consistent we mean that there should be no internal contradictions in the requirements and information provided by the system or to the system.

Statement: 4.1.1.2 The interfaces of the system are consistent.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 201.0 in case of treatment 1 and 465.00 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.2.1.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Response	1	18	11.17	201.00
	2	18	25.83	465.00
	Total	36		

The Mann-Whitney U value is 30 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.2.1.b Test Statistics

	Response
Mann-Whitney U	30.000
Wilcoxon W	201.000
Z	-4.547
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

Statement: 4.1.1.2.b The response time to user's input consistent

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 236.0 in case of treatment 1 and 505.0 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.2.2.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Response	1	20	11.80	236.00
	2	18	28.06	505.00
	Total	38		

The Mann-Whitney U value is 26 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.2.2.b Test statistics

	Response
Mann-Whitney U	26.000
Wilcoxon W	236.000
Z	-4.754
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

4.1.1.3 Complete

By complete information we mean that any essential information about the problem domain is not omitted.

Statement: 4.1.1.3.a The features (requirements) contradict with each other.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 463.5 in case of treatment 1 and 202.50 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.3.1.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Respose	1	18	25.75	463.50
	2	18	11.25	202.50
	Total	36		

The Mann-Whitney U value is 31.50 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.3.1.b Test Statistics

	Respose
Mann-Whitney U	31.500
Wilcoxon W	202.500
Z	-4.538
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

Statement: **4.1.1.3.b** All the inputs given to the system are complete.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 204.0 in case of treatment 1 and 462.0 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.3.2.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Response	1	18	11.33	204.00
	2	18	25.67	462.00
	Total	36		

The Mann-Whitney U value is 33 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.3.2.b Test Statistics

	Response
Mann-Whitney U	33.000
Wilcoxon W	204.000
Z	-4.546
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

4.1.1.4 Un-ambiguous

Requirements should be clear in the sense that they cannot be interpreted in more than one way. No conflicts should be generated from such requirements that lead to dual meanings.

Statement: 4.1.1.4.a The information provided by the is system clear.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 117.50 in case of treatment 1 and 410.15 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.4.1.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Response	1	14	8.39	117.50
	2	18	22.81	410.50
	Total	32		

The Mann-Whitney U value is 12.5 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.4.1.b Test Statistics

	Response
Mann-Whitney U	12.500
Wilcoxon W	117.500
Z	-4.633
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

Statement: 4.1.1.4.b All the terms used in the interface are understandable.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 206.0 in case of treatment 1 and 460.0 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.4.2.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Response	1	18	11.44	206.00
	2	18	25.56	460.00
	Total	36		

The Mann-Whitney U value is 35 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.4.2.b Test Statistics

	Response
Mann-Whitney U	35.000
Wilcoxon W	206.000
Z	-4.279
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

4.1.1.5 According to user's need

The system developed should be according to the needs of its users. The MUST requirements should be present in the system.

Statement: 4.1.1.5.a Satisfaction with the interface of the system.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 193.50 in case of treatment 1 and 472.5 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.5.1.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
Response	1	18	10.75	193.50
	2	18	26.25	472.50
	Total	36		

The Mann-Whitney U value is 22.5 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.5.1.b Test Statistics

	Response
Mann-Whitney U	22.500
Wilcoxon W	193.500
Z	-4.764
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

Statement: 4.1.1.5.b Satisfaction from the accuracy of the system.

In the table below the first value in the Ranks shows the treatments. Treatment "1" shows that the model was not used for requirement validation whereas Treatment "2" shows that the group used the C&C Model for requirement validation. Sum of Ranks is 203.00 in case of treatment 1 and 463.00 in case of treatment 2 from which we can clearly see that there is a great difference between the two treatments.

Table 4.5.2.a Ranks

	Treatment	N	Mean Rank	Sum of Ranks
	1	18	11.28	203.00
Response	2	18	25.72	463.00
	Total	36		

The Mann-Whitney U value is 32 whereas the Asymp.Sig. (2-Tailed) value is .000 which is less than the par value i.e. .05 this shows that there is a significance difference between the two treatments.

Table 4.5.2.b Test Statistics

	Response
Mann-Whitney U	32.000
Wilcoxon W	203.000
Z	-4.563
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000[b]

4.1.2 Statements Frequency and Percentage Analysis.

The results of the frequencies and the percentages of each of the reply are shown in the tables below by using this formula.

$$\text{Average Score} = \frac{n(\text{SA}) \times 5 + n(\text{A}) \times 4 + n(\text{DA}) \times 3 + n(\text{SDA}) \times 2 + n(\text{UD}) \times 1}{n(\text{SA} + \text{A} + \text{DA} + \text{SDA} + \text{UD})}$$

These are the quality attributes or metrics against which we collect data and perform detailed analysis.

- Correct
- Consistency
- Complete
- Un ambiguity
- According to users need

4.1.1.1 Correct:

The formalized requirements should reflect user intentions accurately. Correctness in requirements is simply about getting it right. Correctness applies in a context. "Are these the right requirements to achieve any goal X?"

To determine correctness following questions were asked from the stakeholders some are listed here.

Statement: 4.1.1.1.a Does the prototype provide the required information?

Table 4.1.1 *Prototype provides the required information*

		SA	A	SDA	DA	UD	Total
Without Model	Response	01	02	10	03	02	18

	%age	5.55	11.11	55.5	16.65	11.11	99.92%
	Sum	03		10	05		18
	Mean Score	**2.83**					
With Model	Response	02	15	01	00	00	18
	%age	11.11	83.26	5.55	00	00	99.92%
	Sum	17		01	00		18
	Mean Score	**4.05**					
Difference between Mean Score	**4.05 – 2.83 = 1.22** (With Model – Without Model = Difference)						**1.22**

Results:

Mean Score without Model: 2.83

Mean Score with Model : 4.05

Difference: 1.22

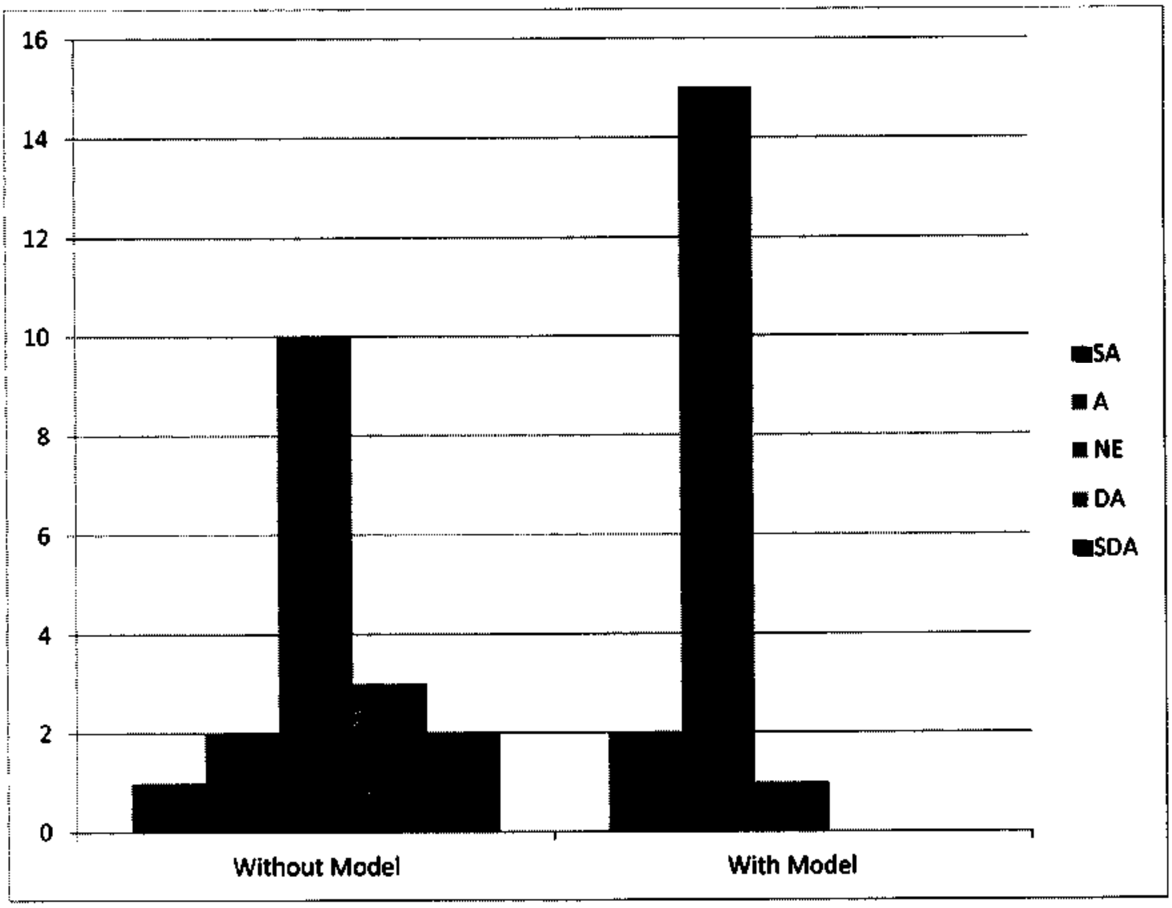
Standard Deviation without Model: 0.957

Standard Deviation with Model: 0.404

Table ***4.1.1*** Indicates that with Model 94.44 % respondents are of the view that "the prototype provide the required information" while 5.55 % respondents are neutral. It also indicates that without Model 16.66 % respondents are of the view that "the prototype provides the required information" while 5.55 % respondents are neutral and 27.72 %

respondents disagreed from the view, which shows that with model results are found more reliable. Moreover the difference in standard deviations of two shows that most of the people agree that prototype provide the required information by using model as compared to that of people without using model.

***Figure 4.1.1** Prototype provides the required information*



Statement: 4.1.11.b The response time to your input was satisfactory.

***Table 4.1.2** The response time to your input satisfactory*

		SA	A	SDA	DA	UD	Total
Without Model	Response	00	03	09	03	03	18
	%age	00	16.65	49.95	16.65	16.65	99.92
	Sum	03		09	06		18
	Mean Score	**2.66**					
With Model	Response	05	12	01	00	00	18
	%age	27.77	66.66	5.55	00	00	99.92
	Sum	17		01	00		18
	Mean Score	**4.22**					
Differences between Mean Score	**4.22 – 2.66 = 1.56** (With Model – Without Model = Difference)					**1.56**	

Results:

Mean Score without Model : **2.66**

Mean Score with Model : **4.22**

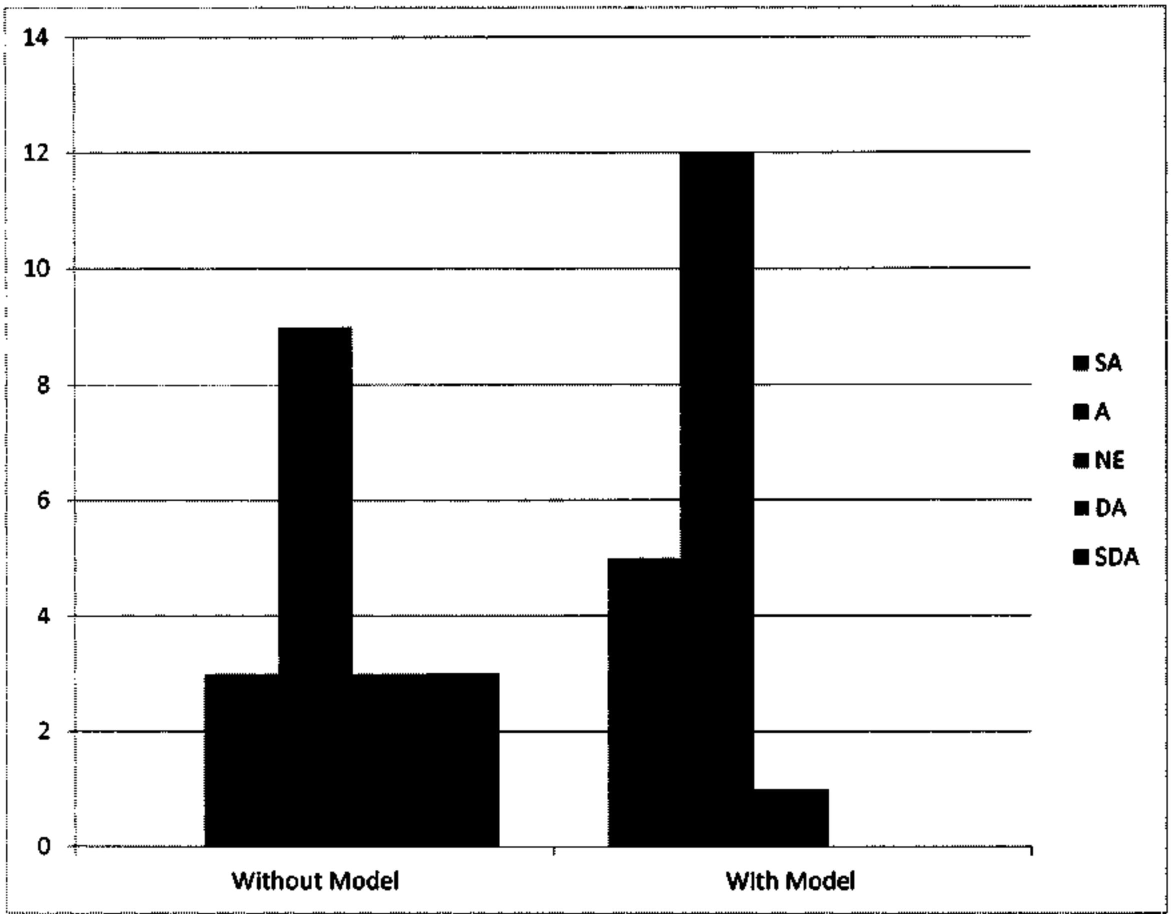
Difference : **1.56**

Standard Deviation without Model: **0.943**

Standard Deviation with Model: 0.533

Table 4.1.2 indicates that with Model 94.44 % respondents are of the view that "the response time of input is satisfactory" while 5.55 % respondents are neutral. It also indicates that without Model 16.65% respondents are of the view that the response time of input is satisfactory" while 49.95% respondents are neutral and 33.3 % respondents disagreed the view, which shows that with model results are found more reliable. The standard deviation of with model shows that most respondents agree that the response time of input is satisfactory as compared to that of without using a model.

Figure 4.1.2 *The response time to your input satisfactory*



4.1.2 Cumulative analysis of all the questions.

These tables show the cumulative analysis of the opinions of the respondents with and without the application of the model.

4.1.2.1 Analysis of answers Model was not used

This is a cumulative analysis of the views and answers of the respondents when they did not use model for communication and coordination in requirement validation through prototyping.

Table : 4.1.3 Opinion of the Respondents Regarding Correctness Without Model

	Statement	Percentage of the different responses					Avg. score
		SA	A	DA	SDA	UD	
1	Does the prototype provide the required information	5.55	11.11	55.5	16.65	11.11	**2.83**
2	Was the response time to your input satisfactory	00	16.65	49.95	16.65	16.65	**2.66**
3	Do all the inputs to the system imitate, what user wants to give to the system, correctly?	00	16.65	55.5	22.2	5.55	**1.83**
4	Do all the outputs to the system imitate, what user want to give to the system, accurately?	00	22.22	44.44	22.22	11.11	**2.22**
5	All the terms and units are us appropriately?	00	27.75	22.22	00	50.00	**2.27**

6	The overall functionality of t software is as expected?	00	11.11	33.33	27.75	27.75	**2.27**
Mean of the average Score							**2.34**

The mean of the average is 2.34 which is little above 2 that means Strongly disagree. So averages of all the above statements show that most of the respondents strongly disagree that without using model they can get the correct requirements.

Most of the responses show that the prototype was not providing them the required information when they were not using the model, and they also strongly disagree that the input and output of their system were correct. Moreover they also disagree that the overall functionality of the system was like what they expected.

4.1.2.2 Analysis of answers Model was used

This is a cumulative analysis of the views and answers of the respondents when they used model for communication and coordination in requirement validation through prototyping.

Table: 4.1.4 Opinion of the Respondents Regarding Correctness with the Model

S. #	Statement	Percentage of the different responses					Avg. score
		SA	A	DA	SDA	UD	
1	Does the prototype provide the required information	11.11	83.26	5.55	00	00	**3.94**
2	Was the response time to your input satisfactory	27.77	66.66	00	00	5.55	**4.11**
3	Do all the inputs to the system imitate, what user wants to give to the system, correctly?	16.65	77.7	00	00	5.55	**4.00**

4	Do all the outputs to the system imitate, what user want to give to the system, accurately?	16.65	77.7	00	00	5.55	**4.00**
5	All the terms and units are used appropriately?	11.1	88.88	00	00	00	**4.11**
6	The overall functionality of the software is as expected?	11.11	83.33	5.55	00	00	**4.05**
Mean of the average Score							**4.03**

The table shows the mean of the average is 4.03 which is near 4 which means Agree. So averages of all the above statements show that most of the respondents agree that with using model they can get the correct requirements.

Most of the responses show that the prototype was providing them the required information when they used the model and they agree that the input and output of their system were correct. Moreover they also agree that the overall functionality of the system was according to what they expected.

4.1.1.2 Consistency

Being consistent we mean that there should be no internal contradictions in the requirements and information provided by the system or to the system.

For this following questions were asked from the stakeholders some are listed here.

Statement: 4.1.1.2 The interfaces of the system are consistent.

Table 4.2.1 interfaces of the system are consistent

		SA	A	SDA	DA	UD	Total
Without Model	Response	00	04	07	04	03	18
	%age	00	22.22	38.88	22.22	16.65	
	Sum	04		07	07		18
	Mean Score	2.66					
With Model	Response	03	15	00	00	00	18
	%age	16.65	83.33	00	00	00	
	Sum	18		00	00		18
	Mean Score	4.16					
Differences between Mean Score	4.16 – 2.66 = 1.5 (With Model – Without Model = Difference)					**1.5**	

Results:

Mean Score without Model : **2.66**

Mean Score with Model : **4.16**

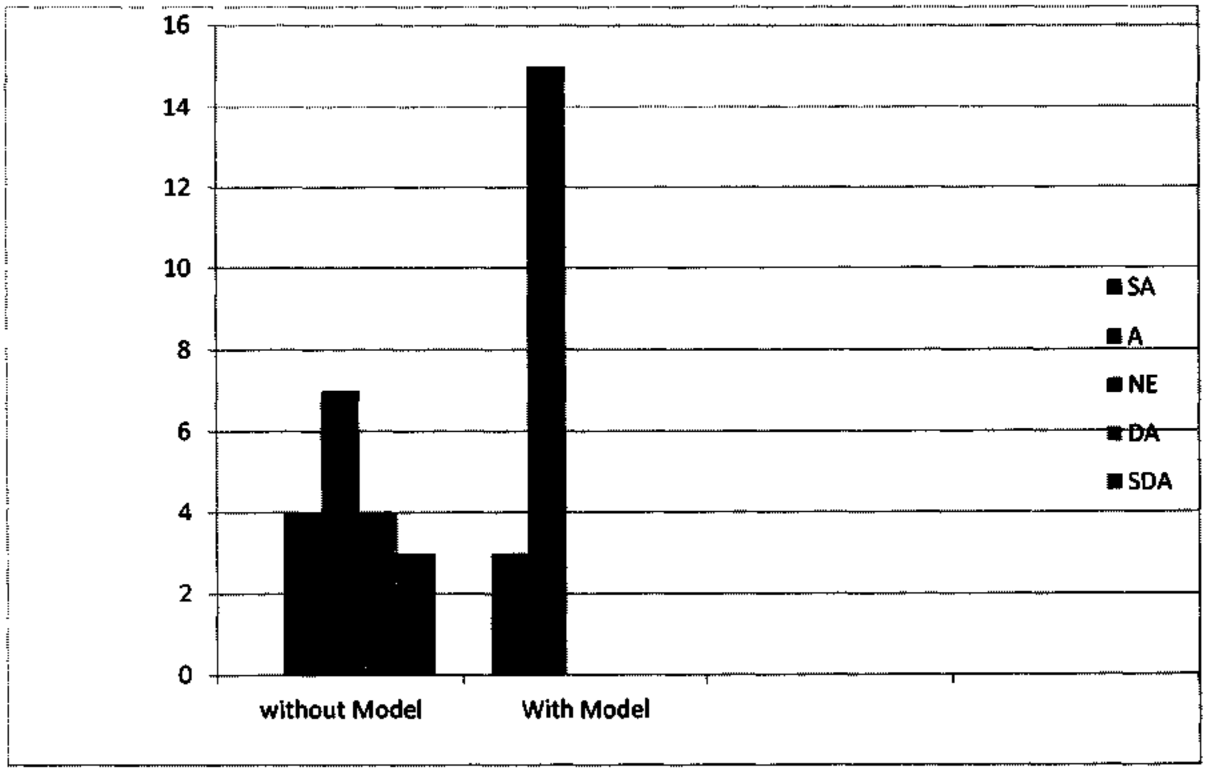
Difference : **1.5**

Standard Deviation without Model: **1.0**

Standard Deviation with Model: **0.373**

Table 4.2.1 indicates that with Model 100 % respondents are of the view that "The interfaces of the system are consistent". It also indicates that without Model 22.22% respondents are of the view that "The interfaces of the system are consistent" 38.88 % respondents are neutral of the view while 38.88 % respondents disagreed with the view, which shows that with model results are found more reliable.

***Figure 4.2.1** interfaces of the system are consistent*



Statement: 4.1.1.2.b The response time to user's input consistent

***Table 4.2.2** The response time to user's input consistent*

		SA	A	SDA	DA	UD	Total
Without Model	Response	00	03	08	03	04	18
	%age	00	16.65	44.44	16.65	22.22	
	Sum	03		08	07		18

	Mean Score	**2.55**					
With Model	Response	05	13	00	00	00	18
	%age	27.75	72.22	00	00	00	
	Sum	18		00	00		18
	Mean Score	**4.27**					
Differences between Mean Score	**4.27 – 2.55 = 1.72** (With Model – Without Model = Difference)						**1.72**

Results:

Mean Score without Model : **2.55**

Mean Score with Model : **4.27**

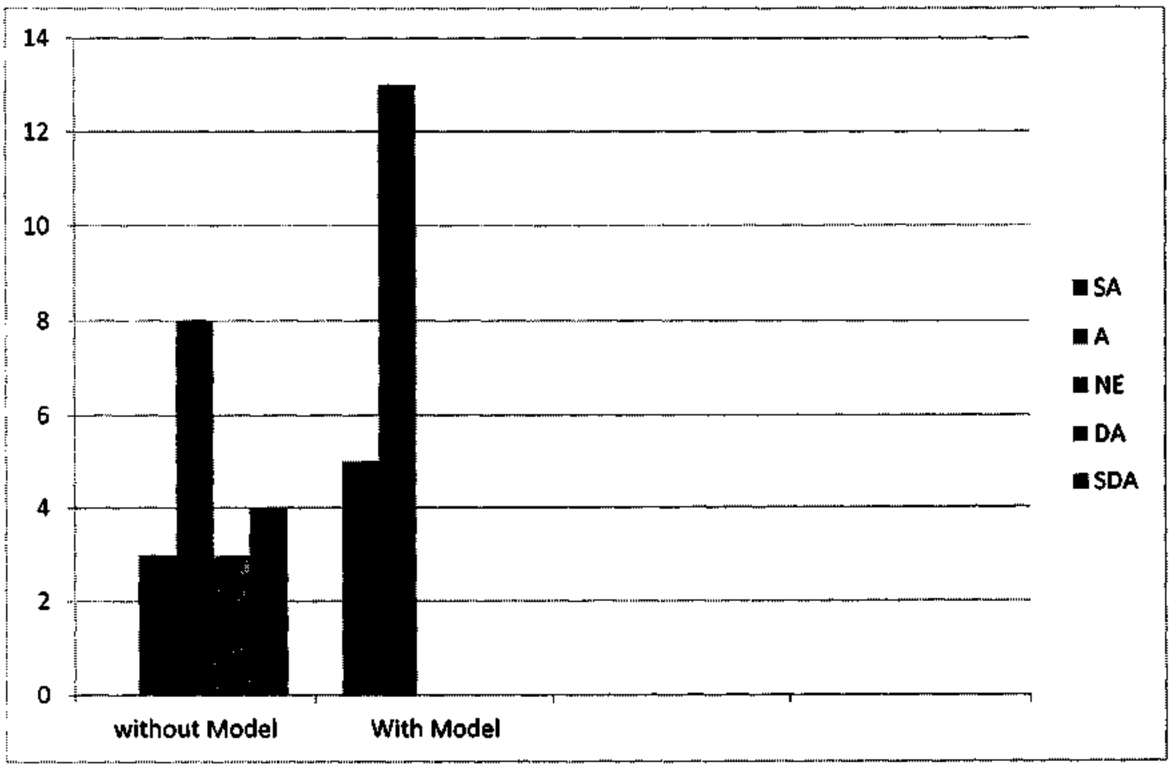
Difference : **1.72**

Standard Deviation without Model: **1.012**

Standard Deviation with Model: **0.448**

Table 4.2.2 indicates that with Model 100% respondents are of the view that "The response time to user's input is consistent". It also indicates that without Model 16.65% respondents are of the view that "The response time to user's input is consistent" 44.44% respondents become neutral while 38.88 % respondents disagreed the view, which shows that with model results are found more reliable.

Figure 4.2.2 *The response time to user's input consistent*



4.1.3 Cumulative analysis of all the questions.

Following tables show the cumulative analysis of the opinions of the respondents about the consistency of requirements with and without the application of the model.

4.1.3.1 Analysis of answers Model was not used

This is a cumulative analysis of the views and answers of the respondents when they did not use model for communication and coordination in requirement validation through prototyping.

Table: 4.2.3 *Opinion of the Respondents Regarding Consistency without Model*

S. #	Statement	Percentage of the different responses					Avg. score
		SA	A	DA	SDA	UD	
1	Are the interfaces of the syste consistent?	00	22.22	22.22	16.65	38.88	**2.27**
2	Is the response time to user's input consistent?	00	16.65	16.65	22.22	44.44	**2.05**
3	Are all the outputs of the system consistent?	00	33.33	16.65	5.55	44.44	**2.38**
4	All the communication requiremer among system/software componer consistent?	00	44.44	16.65	00	38.88	**2.66**
5	Do the features (requiremen contradict with each other?	00	33.33	33.33	11.11	22.22	**2.77**
Mean of the average Score							**2.42**

The mean of the average is 2.42 which is 2 that means Strongly disagree. So averages of all the above statements show that most of the respondents strongly disagree that without using model, they can get the consistency in requirements.

Most of the responses show that the interfaces were not consistent the input and output of the systems are also not consistent. It also shows that they disagree that the features also contradict with each other when they did not use the model.

4.1.3.2 Analysis of answers when Model was used

This is a cumulative analysis of the views and answers of the respondents when they used model for communication and coordination in requirement validation through prototyping.

Table: 4.2.4 *Opinion of the Respondents Regarding "Consistency" After the Application of Model*

S. #	Statement	Percentage of the different responses					
		SA	A	DA	SDA	UD	Avg. score
1	Are the interfaces of the system consistent?	16.65	83.33	00	00	00	**4.16**
2	Is the response time to user's input consistent?	27.75	72.22	00	00	00	**4.27**
3	Are all the outputs of the system consistent?	27.77	72.22	00	00	00	**4.27**
4	All the communication requiremer among system/software componer consistent?	11.11	88.88	00	00	00	**4.11**
5	Do the features (requiremen contradict with each other?	00	00	00	83.33	16.65	**1.83**
Mean of the average Score							**3.72**

The mean of the average is 3.72 which is near 4 which means Agree. So averages of first five statements show that most of the respondents Agree that with using model they can get the consistency in their requirements.

Most of the responses show that the interfaces were consistent and the input and output of the systems are also consistent. It also shows that they agree that the features do not contradict with each other when they use the model. Moreover they strongly disagree that the features contradict with each other when they use the model.

4.1.1.3 Complete

By complete information we mean that any essential information about the problem domain is not omitted.

For this following questions were asked from the stakeholders some are listed here.

Statement: 4.1.1.3.a The features (requirements) contradict with each other.

***Table* 4.3.1** *features contradiction*

		SA	A	SDA	DA	UD	Total
With Model	Response	00	03	12	03	00	18
	%age	00	16.65	66.66	16.65	00	100
	Sum	03		12	03		18
	Mean Score	**3.00**					
Without Model	Response	02	15	01	00	00	18
	%age	11.11	83.33	5.55	00	00	
	Sum	17		01	00		18
	Mean Score	**4.05**					
Differences between Mean Score	**4.05 – 3.00 = 1.05** (With Model – Without Model = Difference)						**1.05**

Results:

Mean Score with Model : 3.00

Mean Score without Model : 4.05

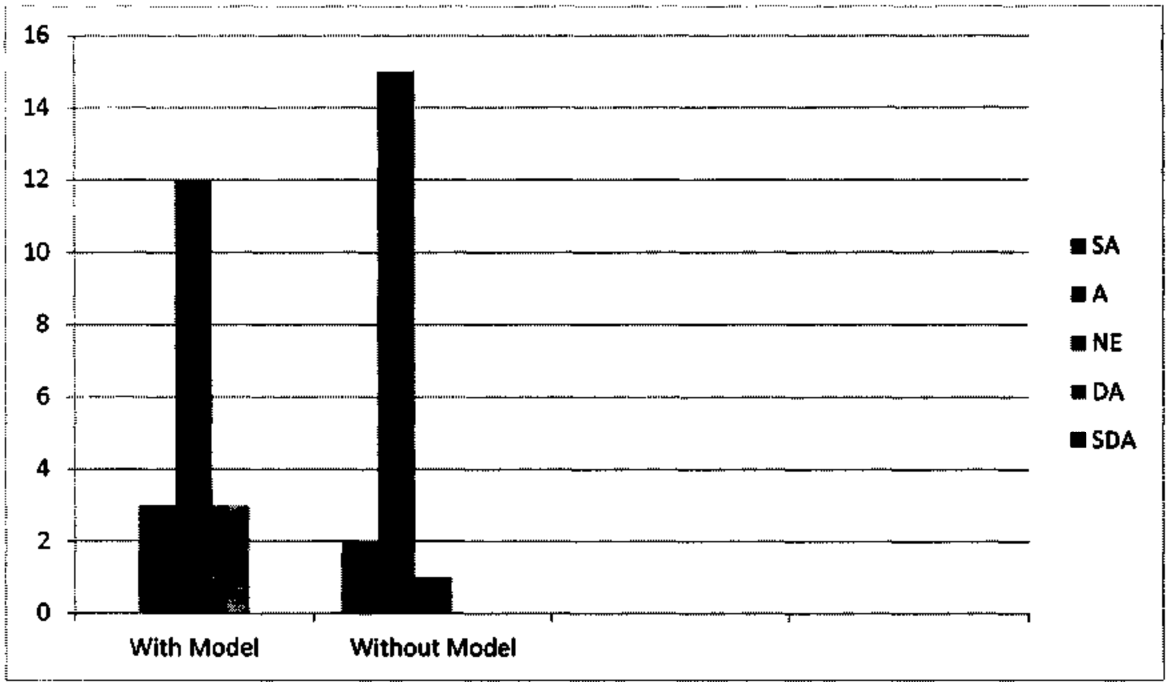
Difference: 1.05

Standard Deviation without Model: 0.577

Standard Deviation with Model: 0.404

Table 4.3.1 indicates that without Model 94.44% respondents are of the view that "The features (requirements) contradict with each other" while 5.5 % respondents are neutral. it also indicates that without Model 16.65 % respondents are of the view that "The features (requirements) contradict with each other" while 66.66 % respondents are neutral and16.65 % respondents disagreed the view, which shows that with model results are found more reliable.

***Figure* 4.3.1** *features contradiction*



Statement: 4.1.1.3.b All the inputs given to the system are complete.

Table 4.3.2 *the inputs given to the system complete*

		SA	A	SDA	DA	UD	Total
Without Model	Response	00	03	12	03	00	18
	%age	00	16.65	66.66	16.65	00	
	Sum	03		12	03		18
	Mean Score	**3.00**					
With Model	Response	01	16	01	00	00	18
	%age	5.55	88.88	5.55	00	00	
	Sum	17		01	00		18
	Mean Score	**4.00**					
Differences between Mean Score	4.00 – 3.00 = 1.00 (With Model – Without Model = Difference)					**1.00**	

Results:

Mean Score without Model : **3.00**

Mean Score with Model : **4.00**

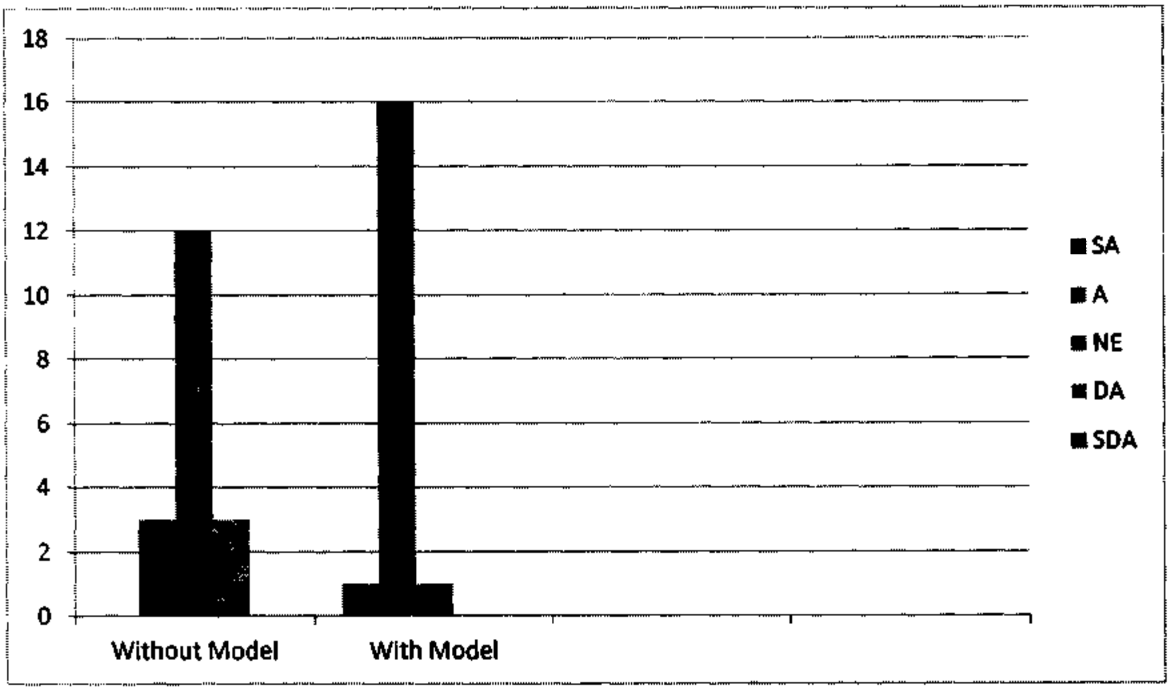
Difference: **1.00**

Standard Deviation without Model: **0.577**

Standard Deviation with Model: **0.333**

Table 4.3.2indicates that with Model 94.44 % respondents are of the view that "All the inputs given to the system are complete" while 5.55 % respondents are neutral. it also indicates that without Model 16.65 % respondents are of the view that "All the inputs given to the system are complete" while 66.66% respondents are neutral and 16.65 % respondents disagreed the view, which shows that with model results are found more reliable.

***Figure* 4.3.2** *the inputs given to the system complete*



4.1.3 Cumulative analysis of all the questions.

Following tables show the cumulative analysis of the opinions of the respondents about the completeness of the requirements with and without the application of the model.

4.1.3.1 Analysis of answers Model was not used

This is a cumulative analysis of the views and answers of the respondents when they did not use model for communication and coordination in requirement validation through prototyping.

Table :4.3.3 *Opinion of the Respondents Regarding Completeness without Model*

S. #	Statement	Percentage of the different responses					Avg. score
		SA	A	DA	SDA	UD	
1	Do the features (requiremen contradict with each other?	11.11	72.22	00	00	16.67	**3.61**
2	Are all the inputs given to t system complete?	00	16.65	16.65	00	66.66	**1.83**
3	Are all the outputs of the system complete?	00	11.11	22.22	11.11	55.55	**1.88**
Mean of the average Score							**2.44**

The mean of the average is 2.44 which is above 2 that means strongly disagree. So averages of all the statements show that most of the respondents strongly disagree that without using model they can get the complete requirements.

For the first statement most of the responses show that the features contradict with each other. For the next two statements the responses show that input and output of the system are not complete when model is not used.

4.3.1.2 Analysis of answers Model was used

This is a cumulative analysis of the views and answers of the respondents when they used model for communication and coordination in requirement validation through prototyping.

Table:4.3.4 *Opinion of the Respondents Regarding Completeness After the Application of Model*

S.#	Statement	Percentage of the different responses					Avg. score
		SA	A	DA	SDA	UD	
1	Do the features (requiremen contradict with each other?	00	5.55	44.44	33.33	16.67	**2.39**
2	Are all the inputs given to t system complete?	27.77	66.67	00	00	5.55	**4.14**
3	Are all the outputs of the system complete?	33.33	61.11	00	00	5.55	**4.17**
Mean of the average Score							**3.60**

The mean of the average is 3.61 which is near 4 which means Agree. So averages of all the statements show that most of the respondents Agree that with using model they can get the complete requirements.

For the first statement most of the responses show that the features do not contradict with each other when the model is used. For the next two statements the responses show that input and output of the system are complete when respondents use the model.

4.1.1.4 Un-ambiguous

Requirements should be clear in the sense that they cannot be interpreted in more than one way. No conflicts should be generated from such requirements that lead to dual meanings.

Statement: 4.1.1.4.a The information provided by the is system clear.

Table* 4.4.1 *The information provided by the is system clear

		SA	A	SDA	DA	UD	Total
Without Model	Response	00	03	11	02	02	18
	%age	00	16.65	61.11	11.11	11.11	
	Sum	03		11	04		18
	Mean Score	**3.83**					
With Model	Response	03	14	01	00	00	18
	%age	16.65	77.77	5.55	00	00	
	Sum	17		01	00		18
	Mean Score	**4.11**					
Differences between Mean Score	**4.11 – 3.83 = 0.28** (With Model – Without Model = Difference)					**0.28**	

Results:

Mean Score without Model : 2.83

Mean Score with Model : 4.11

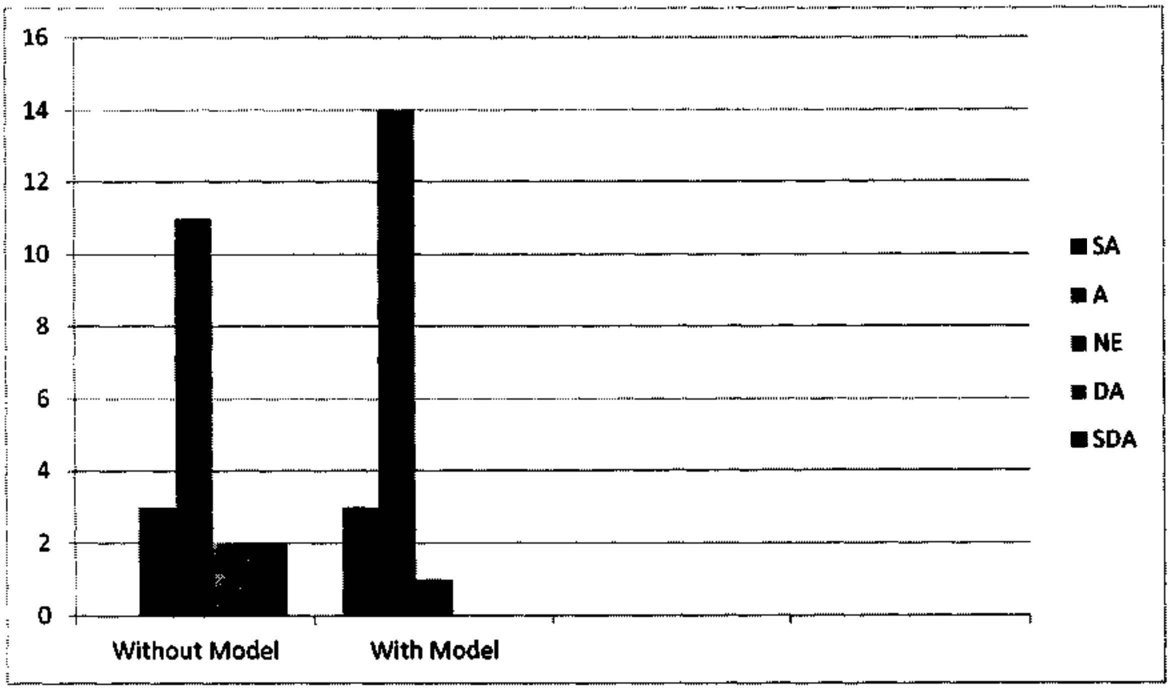
Difference: 0.28

Standard Deviation without Model: 1.299

Standard Deviation with Model: 0.458

Table **4.4.1** indicates that without Model 94.44 % respondents are of the view that "Clear information is provided by the system" while 5.55% respondents are neutral. it also indicates that without Model 16.65 % respondents are of the view that "Clear information are provided by the system ," while61.11 % respondents become neutral and 22.22% respondents disagreed the view, which shows that with model results are found more reliable.

***Figure* 4.4.1** *The information provided by the is system clear*



Statement: 4.1.1.4.b All the terms used in the interface are understandable.

***Table* 4.4.2** *All the terms used in the interface are understandable*

		SA	A	SDA	DA	UD	Total
Without Model	Response	00	03	11	03	01	18
	%age	00	16.65	61.11	16.65	5.55	
	Sum	03		11	04		18
	Mean Score	**2.88**					

With Model	Response	04	13	01	00	00	18
	%age	22.22	72.22	5.55	00	00	
	Sum	17		01	00		18
	Mean Score	**4.16**					
Differences between Mean Score	**4.16 – 2.88 = 1.28** (With Model – Without Model = Difference)						**1.28**

Results:

Mean Score without Model : **2.88**

Mean Score with Model : **4.16**

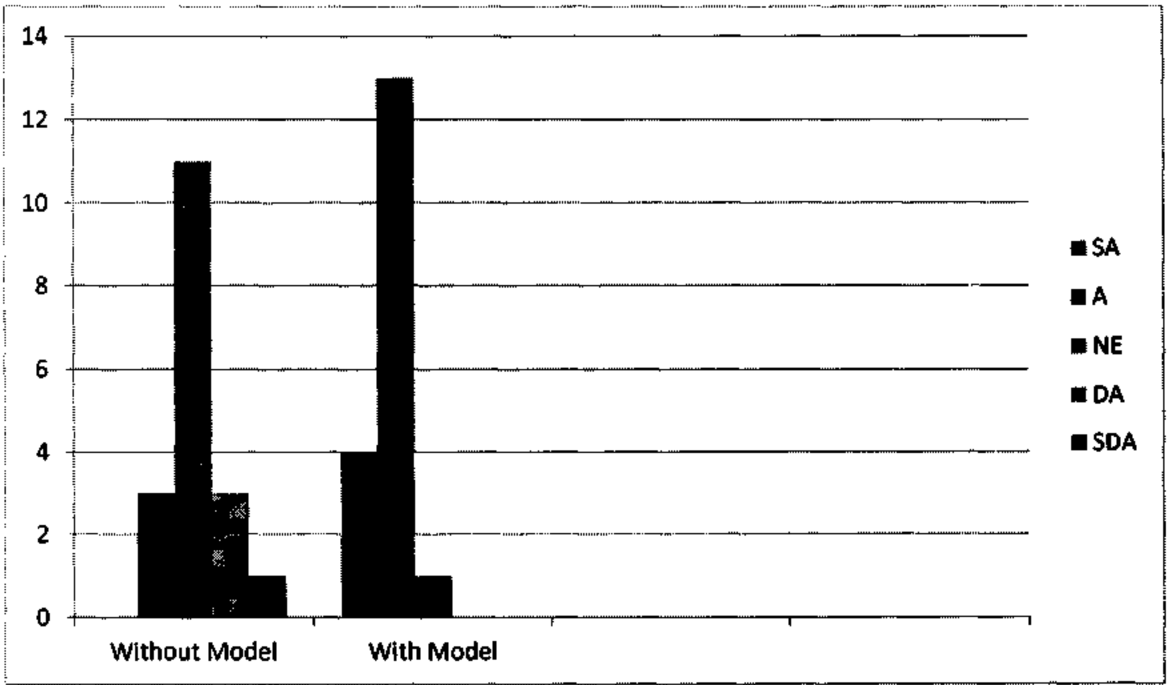
Difference: **1.28**

Standard Deviation without Model: **0.737**

Standard Deviation with Model: **0.50**

Table **4.4.2** indicates that with Model 94.44 % respondents are of the view that "Are all the terms used in the interface understandable" while 5.55% respondents become neutral. It also indicates that without Model 16.65% respondents are of the view that "Are all the terms used in the interface understandable" while 61.11 % respondents become neutral and 22.22% respondents disagreed the view, which shows that with model results are found more reliable.

***Figure* 4.4.2** *All the terms used in the interface are understandable*



4.1.4 Cumulative analysis of all the questions.

These tables show the cumulative analysis of the opinions of the respondents regarding ambiguity of requirements with and without the application of the model.

4.1.4.1 Analysis of answers Model was not used

This is a cumulative analysis of the views and answers of the respondents when they did not use model for communication and coordination in requirement validation through prototyping.

Table:4.4.3 *Opinion of the Respondents Regarding Un-ambiguous Without Model*

S.#	Statement		Percentage of the different responses				
		SA	A	DA	SDA	UD	Avg. score
1	Is the information provided by the system clear?	00	16.65	11.11	11.11	61.11	**1.83**

2	Are all the terms used in t interface understandable?	00	16.65	16.65	5.55	61.11	**1.88**
3	Are all the inputs given to t system by you unambiguous?	00	16.65	16.65	5.55	61.11	**1.88**
4	Are all outputs from the syste unambiguous?	00	16.65	16.65	5.55	61.11	**1.88**
5	Are the interfaces unambiguous?	22.22	22.22	11.11	00	44.44	**2.77**
6	Have user requirements been interpreted in the expected way.	00	16.65	16.65	11.11	55.55	**1.94**
	Mean of the average						**2.03**

The mean of the average is 2.03 which is almost 2 which means strongly disagree. So averages of all the statements show that most of the respondents strongly disagree that they got un-ambiguity in their requirement without using model.

Most of the responses show that the terms used in the interface were not clear and understandable, the input and output of the system were very ambiguous when the model was not used. Moreover they also said that their requirements were not interpreted in the expected way.

4.1.4.2 Analysis of answers when Model was used

This is a cumulative analysis of the views and answers of the respondents when they used model for communication and coordination in requirement validation through prototyping.

Table: 4.4.4 *Opinion of the Respondents Regarding Un-ambiguous with Model*

S.#	Statement	Percentage of the different responses					
		SA	A	DA	SDA	UD	Avg. score
1	Is the information provided by the system clear?	16.65	77.77	00	00	5.55	**4.00**
2	Are all the terms used in the interface understandable?	22.22	72.22	00	00	5.55	**4.05**
3	Are all the inputs given to t system by you unambiguous?	11.11	88.88	00	00	00	**4.11**
4	Are all outputs from the system unambiguous?	11.11	88.88	00	00	00	**4.11**
5	Are the interfaces unambiguous?	16.65	83.33	00	00	00	**4.16**
6	Have user requirements been interpreted in the expected way.	22.22	77.77	00	00	00	**4.22**
	Mean of the average Score						**4.10**

The mean of the average is 4.10 which is near 4 which means Agree. So averages of all the statements show that most of the respondents Agree that they got un-ambiguity in their requirement while using model.

Most of the responses show that the terms used in the interface were very clear and understandable, the input, output and the interfaces of the system were unambiguous. Moreover most of the respondents also agreed that the requirements were interpreted in the expected way when they use the model for communication and coordination of their product.

4.1.1.6 According to user's need

The system developed should be according to the needs of its users. The MUST requirements should be present in the system.

For this following questions were asked from the stakeholders some are listed here.

Statement: 4.1.1.5.a Satisfaction with the interface of the system.

***Table* 4.5.1** *Satisfaction with the interface of the system*

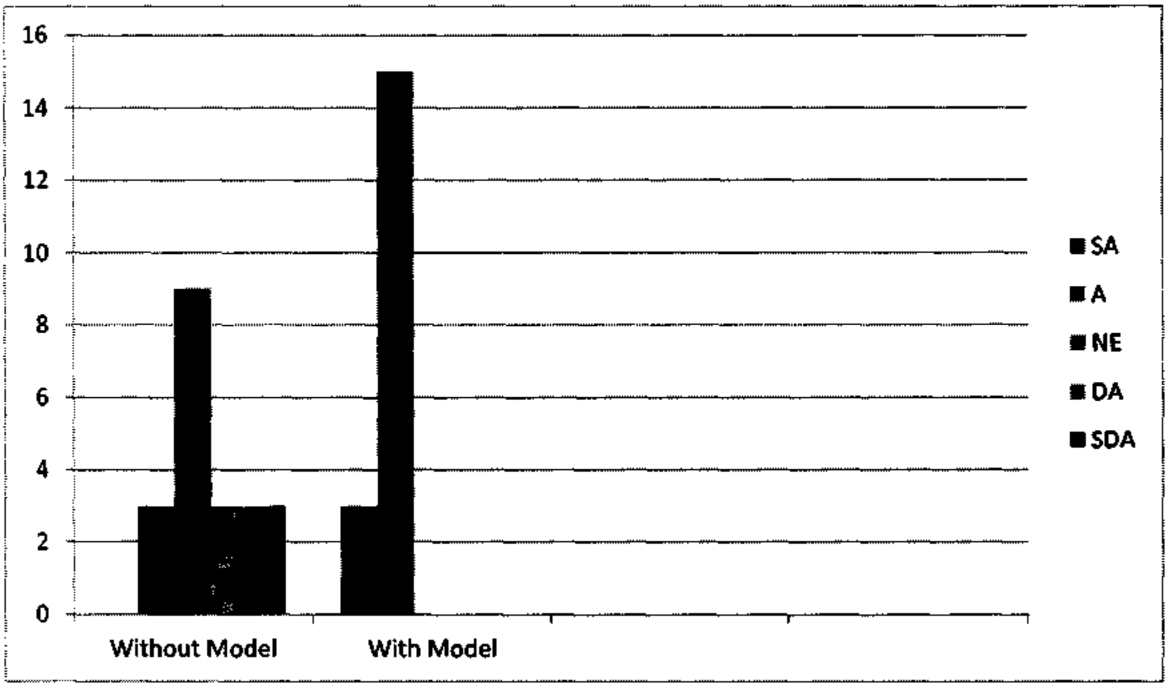
		SA	**A**	**SDA**	**DA**	**UD**	**Total**
Without Model	Response	00	03	09	03	03	18
	%age	00	16.65	50.00	16.65	16.65	
	Sum	03		09	06		18
	Mean Score	**2.66**					
With Model	Response	03	15	00	00	00	18
	%age	16.65	83.33	00	00	00	
	Sum	18		00	00		18
	Mean Score	**4.16**					
Differences between Mean Score	**4.16 – 2.66 = 1.50** (With Model – Without Model = Difference)						**1.50**

Results:

Mean Score without Model :	**2.66**
Mean Score with Model :	**4.16**
Difference:	**1.50**
Standard Deviation without Model:	**0.942**
Standard Deviation with Model:	**0.373**

Table 4.5.1 indicates that with Model 100% respondents are of the view that "Interface of the system is satisfactory" while 0 % respondents disagreed the view and 0 % are neutral. It also indicates that without Model 16.65% respondents are of the view that "Interface of the system is satisfactory " while 50 % respondents become neutral and 33.33% respondents disagreed the view, which shows that with model results are found more reliable.

***Figure* 4.5.1** *Satisfaction with the interface of the system*



Statement: 4.1.1.5.b Satisfaction from the accuracy of the system.

***Table* 4.5.2** *Satisfaction from the accuracy of the system*

		SA	A	SDA	DA	UD	Total
Without Model	Response	00	04	09	03	02	18
	%age	00	22.22	50	16.65	11.11	
	Sum	04		09	05		18
	Mean Score	**2.83**					
With Model	Response	02	16	00	00	00	18
	%age	11.11	88.88	00	00	00	
	Sum	18		00	00		18
	Mean Score	**4.11**					
Differences between Mean Score	**4.11 – 2.83 = 1.28** (With Model – Without Model = Difference)					**1.28**	

Results:

Mean Score without Model: **2.83**

Mean Score with Model : **4.11**

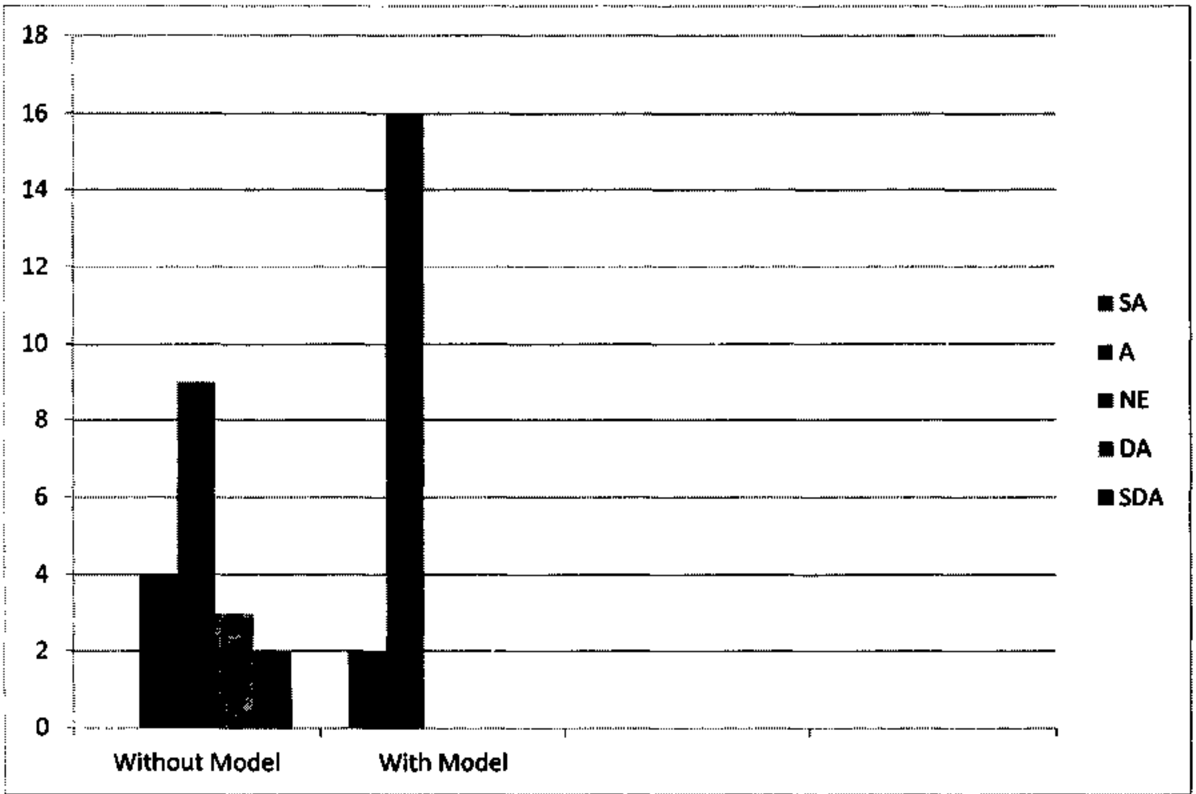
Difference: **1.28**

Standard Deviation without Model: **0.897**

Standard Deviation with Model: **0.314**

Table 4.5.2 indicates that with Model 100 % respondents are of the view that "Accuracy of the system for user is satisfactory". it also indicates that without Model 22.22 % respondents are of the view that "Accuracy of the system for user is satisfactory" while 50 % respondents become neutral while 27.77% respondents disagreed the view, which shows that with model results are found more reliable.

***Figure* 4.5.2** *Satisfaction from the accuracy of the system*



4.1.5 Cumulative analysis of all the questions.

These tables show the cumulative analysis of the opinions of the respondents with and without the application of the model.

4.1.5.1 Analysis of answers Model was not used

This is a cumulative analysis of the views and answers of the respondents when they did not use model for communication and coordination in requirement validation through prototyping.

Table:4.5.3 *Opinion of the Respondents Regarding "According to user's need" Without Model*

S.#	Statement	Percentage of the different responses					
		SA	A	DA	SDA	UD	Avg. score
1	Are you satisfied with the interface of the system?	00	16.65	16.65	16.65	50.00	**2.00**
2	Are you satisfied with t accuracy of the system?	00	22.22	16.67	11.11	50	**2.11**
3	Are the access rights working as required?	00	27.78	16.67	5.55	50.00	**2.22**
4	Do you need special training to work on the system	16.65	27.77	16.65	11.11	27.77	**2.94**
5	Did requested features fulfill t required standards?	11.11	27.77	11.11	5.55	44.44	**2.55**
Mean of the average Score							**2.36**

The mean of the average is 2.36 which is 2 which means strongly disagree. So averages of all the statements show that most of the respondents strongly disagree that the requirements were not according to what they needed when they were not using model.

Most of the respondents say that they are not satisfied with the interfaces and accuracy of the system and they need special training for the understanding of the system as most of the things were unclear and not up to their required standard.

4.1.5.2 Analysis of answers Model was used

This is a cumulative analysis of the views and answers of the respondents when they used model for communication and coordination in requirement validation through prototyping.

Table:4.5.4 *Opinion of the Respondents Regarding According to user's need with Model*

S.#	Statement	Percentage of the different responses					
		SA	A	DA	SDA	UD	Avg. score
1	Are you satisfied with the interface of the system?	16.65	83.33	00	00	00	**4.16**
2	Are you satisfied with the accuracy the system?	11.11	88.88	00	00	00	**4.11**
3	Are the access rights working as required?	33.33	66.66	00	00	00	**4.33**
4	Do you need special training to work on the system	16.65	83.33	00	00	00	**4.16**
5	Did requested features fulfill t required standards?	16.65	83.33	00	00	00	**4.16**
Mean of the average Score							**4.18**

The mean of the average is 4.18 which is almost 4 which means Agree. So averages of all the statements show that most of the respondents Agree that the requirements were according to what they needed when they used model.

Most of the respondents agree that they are satisfied with the interfaces and accuracy of the system and they do not need any special training for the understanding of the system as most of the things were clear and up to their required standard.

4.2 Qualitative Analysis

In addition to the quantitative analysis a qualitative analysis was also performed. The qualitative analysis was done on the data collected from open ended questions.

At the end of each treatment each member was given another questionnaire in which open ended questions were asked in order to get their views about the experiment and the Model. This analysis provides us with the confidence in the results of crossover experiment design. Like in one question it was asked "*Did you find communication and coordination easier with using model or without using model and how?*" almost every member replied that they found communication and coordination easier with Model and one of them replied as "*I found Communication easier with model as it allowed real time responses within the co-located end-user team. Most of the problems were solved before being sent in email to the developers and domain expert team leads.*"

In another question it was asked "*Was using Model for validation a success or not?*" *and majority of them replied that it was a success*" and one of them replied as "*Using model was a good experience for all our team members as we can better understand the problems by mutual discussion and it didn't make mess by communicating every single person of other groups. So overall the model used for validating was a success.*"

4.3 Findings from Quantitative and Qualitative Analysis

Above mentioned detailed analysis has shown that the requirement validation done by using a model gives us better results as compared to that of not using a model as the results show the correctness, consistency, un-ambiguity,. Hence we can say that using Model is a better way to communicate and coordinate as it provides us with fewer links among users, software developers and Domain Experts whereas without using Model each person of one group can communicate with every other member of second group which makes communication more ambiguous, incomplete, incorrect and unsatisfactory for the users.

We use Mann-Whitney U-Test for analysis of our data as it was not normally distributed and sample size was limited so the best case to use Mann-Whitney test. From the results of this test and the difference of the Ranks in it clearly shows that there is a significance difference between the results of the two treatments, so we can say that users are more satisfied with the use of model as compared to when they did not use it.

It is clearly seen from the statement wise as well as cumulative analysis that the opinions of the respondents are highly positive when they use the model as compared to when they did not use the model. They said that the back and forth communication was smooth, there were less natural language issues, there was less delay in feedback, no conflicting feedback, no mix-up of e-mails, they had a common understanding of the requirements, there were very clear communication paths, there was direct communication between the stakeholders when they used the proposed model.

The table (4.1.3) shows the mean of averages as *'2'* which represents *'Strongly Disagree'*, so this shows that most of the respondents strongly disagree that they get correct requirements while not using a model. Whereas the table (4.1.4) shows that the mean of the averages was *'4'* which represents *'Agree'*, so this shows that most of the respondents agree that they get the correct requirements when they apply model.

The table (4.2.3) shows the mean of averages as *'2'* which represents *'Strongly Disagree'*, so this shows that most of the respondents strongly disagree that they get consistent requirement while not using a model. Whereas the table (4.2.4) shows that the mean of the averages was *'4'* which represents *'Agree'*, so this shows that most of the respondents agree that they get the consistent requirements when they apply model.

The table (4.3.3) shows the mean of averages as *'2'* which represents *'Strongly Disagree'*, so this shows that most of the respondents strongly disagree that they get complete requirements while not using a model. Whereas the table (4.3.4) shows that the mean of the averages was *'4'* which represents *'Agree'*, so this shows that most of the respondents agree that they get the complete requirements when they apply model.

The table (4.4.3) shows the mean of averages as *'2'* which represents *'Strongly Disagree'*, so this shows that most of the respondents strongly disagree that they get un-ambiguous requirements while not using a model. Whereas the table (4.4.4) shows that the mean of the averages was *'4'* which represents *'Agree'*, so this shows that most of the respondents agree that they get the un-ambiguous requirements when they apply model.

The table (4.5.3) shows the mean of averages as *'2'* which represents *'Strongly Disagree'*, so this shows that most of the respondents strongly disagree that they get requirements according to their needs while not using a model. Whereas the table (4.5.4) shows that the mean of the averages was *'4'* which represents *'Agree'*, so this shows that most of the respondents agree that they get the requirements according to their needs when they apply model.

Whereas as observed from the communication patterns in the email and reinforcement from interviews, it is established that the major pitfall in achieving project goals for treatment without using model was the communication breakdown, unambiguous requirements, hindrance in establishing a shared mental model for the project and its requirements. This eventually led to wasted time, cost and a system that did not satisfy user.

Hence, most of the respondents found communication and coordination easier with model as that of without model, and majority of them said that they had a good experience for better understanding of the problems, the requirements gathered were very clear and unambiguous when they were working with model as compared to that of without model because there were many nodes in without model which made mess and sometimes formed ambiguity.

5. Conclusion

This chapter discusses the conclusion and future prospects of this research.

5.1 Contributions of research

Globalization has increased from the past few years and is still increasing at a reasonable pace particularly for software engineering. Software engineering has many phases that can be distributed globally. Multi-site development has many benefits such as cost reduction, access to multi-skilled workers, time saving etc. On the other hand requirements engineering is difficult enough when done in a traditional collocated environment, it becomes even more difficult when stakeholders have to specify requirements across cultural, language and time zone boundaries [D. Damian and D. Zowghi, 2003, 2006]. One of the important and critical activities of software engineering is requirement validation which can be accomplished with the help of many techniques. [Nuseibeh, Easterbrook, 2000]. RV is a communication-intensive activity and requires interactions between a diverse group of people including analysts, customers of the intended system and users in the problem domain. [Loucopoulos, P. and Karakostas, V. (eds), (1995)].

In a previous study various techniques for requirement validation in global software development were discussed and a framework was proposed to study these techniques. The study concluded that prototyping is the best technique for requirement validation in global software development environment. G.S.D creates significant communication and coordination challenges that impact the effectiveness of requirement engineering between distributed sites. [Wes J. Lloyd, 2001]. For communication and coordination issues like language and cultural barriers, physical distance issues, lack of Informal Communication, lack of Shared Understanding etc. A model was proposed in a previous work. [Asma, 2011].

Literature identifies the attributes for verifying the quality requirements through SRS etc. but does not tell how we can validate the requirements on the basis of these attributes. Therefore the main goal of this research was to study the different quality attributes from literature, a metric was defined and a checklist was prepared. Requirements were validated according to this prepared checklist. This will help us in better foundation for a good product and ultimately user satisfaction.

Thus the alternative hypothesis of this research was *"There is significant difference between the requirement validation activity performed with or without using the communication and coordination model."* A controlled experiment was performed to check the effectiveness of proposed communication and coordination model for GSD. The experiment involved students from two different universities, one from England and other from Pakistan. Students were asked to validate the requirements with and without the model to gauge its effectiveness.

After experiment execution and applying different tests like Mann-Whitney U-Test and Average and Percentage Analysis it was found that users were more satisfied when they used the C & C Model as compared to when they did not use it. As when model was not used usually every single person of one group communicates with every single person of other group, which created a lot of problems in understanding requirements and resulted in messy communication links leading to confusion. In the end the requirements were not very clear, sometimes in-complete and most of the times they were ambiguous. On the other hand when the model was used the requirements were clear, very precise, complete, and understandable to all stakeholders and depicted the needs of the stakeholders. Similarly while conducting the experiment there were a lot of problems we faced like time-difference between the two countries, the language barrier, the medium of communication etc. but these problems were less when the model was used as there were fewer communication links and due to intra-communication there was a better understanding of the problems among groups as compared to when the model was not used. These problems almost got double in that case.

Hence, on the basis of the results from post experiment questionnaire and applying different statistical tests like Mann-Whitney U-Test and Average and Percentage Analysis technique we incur that requirement's validation activity is performed in a better way when using the communication and coordination model as compared to that of not using a model. Moreover the respondents were more satisfied that model helped them in solving their problems in communication and coordination that came due to globally distributed sites. The requirements were correct, complete, consistent, un-ambiguous and they were according to what user demanded.

5.2 Recommendations and future work

Requirement Validation in global software development is a challenging task and can be carried out by adopting right techniques and methods. This can save much time and efforts.

A Controlled experiment is limited; the model can be checked in a real world case study and projects. There is a need to do more research to validate the model on different types of software engineering projects especially on small and medium type projects to ensure the claim that the model is generic and can serve a wide variety of software projects. Moreover, only prototyping technique is used for requirement validation and tool is implemented on that. This model can also be used on other requirement validation techniques such as animation, inspection and natural language to better gauge the strengths and weaknesses of this model.

The development of a communication and coordination tool which is implementing this model can be beneficial for proper checking. It is our belief that further research in this area would highly benefit the requirements validation process in geographically distributed settings.

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