USER-CENTRIC REQUIREMENTS ELICITATION FRAMEWORK FOR GLOBAL SOFTWARE DEVELOPMENT TEAMS

BY

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ABSTRACT

The requirements elicitation is considered as the foremost important activity of software development process with ultimate goal of requirements finalization for anticipated project. It is well accepted in the software engineering domain that an effective requirements elicitation process vitally contributes in success of software development endeavors. It is evident from the available state-of-art literature and industry practices that requirements elicitation process is critically dependent on participant’s personality traits due to its highly social and collaborative context. Furthermore, the role of user’s personality traits becomes a core pivot for requirements elicitation process in traditional inhouse as-well-as modern global software development practices. In global software development context, the role of user’s personality traits in requirements elicitation process is further raised due to high variations in user’s geographical locations having different cultural norms. Moreover, the user’s personality traits-based user-centricness in requirements elicitation process greatly improves the overall process of requirements elicitation. Accordingly, there was a serious need to formulate a novel user-centric requirements elicitation framework incorporated with user’s personality traits for global software development teams. In order to inspect this imperative issue, the dependency of requirements elicitation process on user’s personality traits is investigated to find the impact of user’s personality traits on requirements elicitation process. Consequentially, a user-centric requirements elicitation framework has been devised for global software development teams. The applicability and validity of the proposed framework has been evaluated using experimental approach at academic level pilot-test as-well-as industry level real-test. The evaluation results highlighted an overall quality improvement of 11.3% in requirements elicitation process for global software development teams. The evaluation results also revealed a more specific improvement of 31.6% in quality factor of correctness, 31.1% in quality factor of completeness and 20.6% in quality factor of consistency. The obtained results have fully justified the applicability of the formulated framework in the domain of software engineering.
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خلاصة البحث

يعتبر تحديد المتطلبات واحتياجات البرامج أهم خطوة في عملية تطوير البرمجيات وذلك لوضع اللمسات الأخيرة والصيغة النهائية للاحتياجات المتعلقة بالمشروع المتوقع. ومن الطبيعي جيداً في مجال هندسة البرمجيات أن عملية تحديد المتطلبات فعالة تساهم بشكل حيوي في نجاح مساعي تطوير البرمجيات. ويتضمن ذلك من خلال أحدث الدراسات الاكاديمية الصناعية المتاحة أن عملية الاستنباط وتحديد المتطلبات تعتمد بشكل حاسم على سمات الشخصية المشارك نظرا لسياقها الاجتماعي والتعاون. علاوة على ذلك، يصبح دور للسمات الشخصية للمستخدم محورا لعملية تحديد هذه المتطلبات في ممارسة تطوير البرمجيات الداخلية التقليدية فضلا عن ممارسة تطوير البرمجيات العلمية الحدية. وفي السياق العالمي لاطوير البرمجيات، يتزايد دور السمات الشخصية للمستخدم في عملية تحديد المتطلبات بسبب الاختلافات الكبيرة في الموقيع الجغرافية ذات المعايير الثقافة المختلفة. أضف إلى ذلك، فإن تركيز المستخدم على سمات شخصية المستخدم في عملية تحديد المتطلبات يؤدي إلى تحسين كبير في العملية الشاملة لتحديد هذه المتطلبات. وبناء على ذلك، كانت هناك حاجة ماسة إلى صياغة إطار جديد لتحديد المتطلبات تركز على المستخدم وإدماجها مع سمات شخصية المستخدم بالنسبة لفرق تطوير البرمجيات العالمية.ومن أجل الكشف عن هذه المشكلة، تم التحقيق في اعتماد عملية تحديد المتطلبات على السمات الشخصية للمستخدم لمعرفة تأثيرها على عملية تحديد هذه المتطلبات حيث تم وضع إطار عمل لتحديد المتطلبات يركز على مستخدمي فرق تطوير البرمجبات العالمية. تم تقييم مدى قابلة تطبيق الإطار المقترح وصلاحيته باستخدام النهج التجريبي في الاختبار التجريبي على المستوى الأكاديمي وكذلك الاختبار الحقيقي على المستوى الصناعي. أبرزت نتائج التقييم تحسنا عاما في الجودة بنسبة 11.3٪ في عملية أستنباط وتحديد المتطلبات واحتياجات البرامج لفرق تطوير البرمجيات العالمية. كما كشف نتائج التقييم عن تحسن أكثر تحديدا بنسبة 31.6٪ في معامل الجودة للصحة ، و 31.1٪ في عامل الجودة للاكتمال و 20.6٪ في عامل الجودة التناسق. كما برزت النتائج التي تم الحصول عليها كامل قابلية تطبيق الإطار المصاغ في مجال هندسة البرمجيات.

APPROVAL PAGE

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DECLARATION

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Firstly, it is my utmost pleasure to dedicate this work to my dear parents and my family, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience.

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INTRODUCTION

1.1 BACKGROUND

The software engineering domain emerged to overcome the software development complexities and difficulties by providing good practices for software developers (Akbar, et al., 2018). The software engineering practices enabled the software development industry to develop good quality software to meet the user expectations. The researchers from the domain of software engineering proposed a large number of good practices in form of software development processes in last few decades (Araújo, et al., 2020). The quality of the software has been assured by using good practices of software development with different software quality assurance mechanisms. The software engineering practices provide systematic ways to develop good quality software through a structured approach known as software development life cycle. The software development life cycle defines a philosophical model for developing good quality software using well-defined methodology. The requirements engineering is first stage of software development lifecycle with ultimate goal of requirements gathering and documentation for product.

1.1.1 Requirements Engineering

The *Requirements Engineering (RE)* is considered as the most important activity performed during software development life cycle as front-line process to gather requirements from stakeholders (Burnay, et al., 2020). The requirements engineering process is divided into two main phase including requirements development phase and requirements management phase. The requirements development phase is further decomposed of four sub-stages including requirements elicitation stage, requirements analysis stage, requirements specifications stage and requirements validation stage. The requirements elicitation stage is concerned with eliciting requirements from different stakeholders of product using different requirements elicitation techniques (Cirqueira, et al., 2020). The requirements analysis stage is concerned with analyzing the elicited requirements to find out any ambiguities, redundancies, inconsistencies, incompleteness, verifiability, measurability, conciseness, understandability and traceability. The requirements specifications stage is concerned with documenting the agreed requirements in an approved template to formulate a formal deliverable of requirements engineering process. The requirements validation stage is concerned with reviewing the documented requirements and confirming them from product users for their final approval as requirements baseline document. The requirements management process is concerned with managing the changes in the requirements baseline document and proceed control mechanism to implement all desired changes through a systematic change control process (Alsanad & Chikh, 2017). Consider figure-1.1, which explains the different stages of requirements engineering process with their sub-stages and different activities carried out during each stage.

The software requirements are described at different levels of abstractions depending upon the type of requirements, source of requirements and context of elicitation scenario (Groen, et al., 2017). The software requirements are usually described at three different levels of abstractions including business level requirements, user level requirements and product level requirements. The hierarchy of requirements comprised of these three abstraction levels is shown in the figure-1.2. The business level requirements define the business objectives of the client organization that can be achieved by using the desired software product (Wagner, Fernández, Kalinowski, & Felderer, 2018).

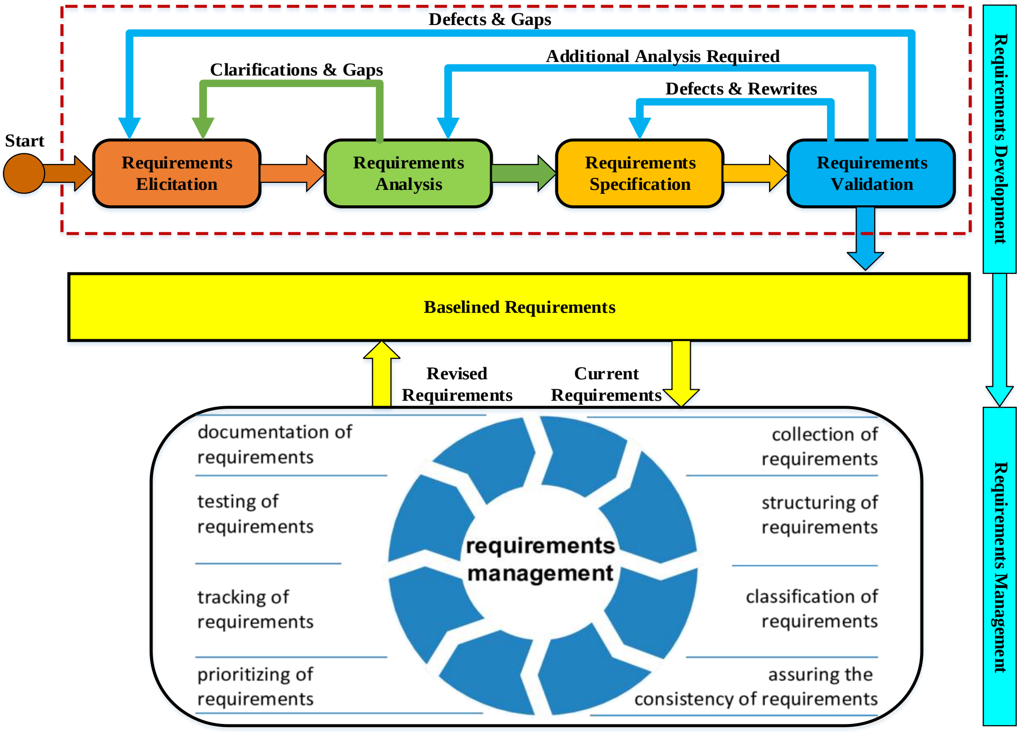


Figure-1.1: Requirements Engineering Process (Dermeval, et al., 2015)

The business level requirements generally give the broad spectrum about features and functionalities of the product. The user requirements further add details to business level requirements by providing descriptions of the features from the user perspectives (Thew & Sutcliffe, 2017). The user level requirements describe the tasks that can be accomplished by system users to meet the high-level business requirements. The product level requirements are documented in form of software requirements specifications, which comprised of functional requirements, non-functional requirements, external interface requirements, data requirements and system constrains (Dar, et al., 2020).

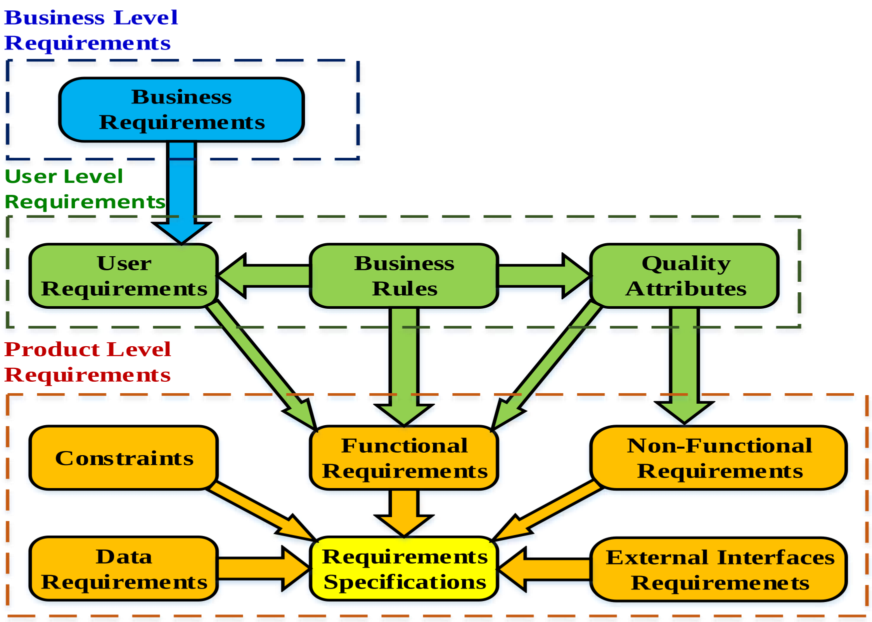


Figure-1.2: Levels of Software Requirements (Horkoff, et al., 2017)

1.1.2 Requirements Elicitation Process

The requirements engineering process is essentially an iterative process accomplished as a spiral model which consists of four stages including requirements elicitation stage, requirements analysis stage, requirements specifications stage and requirements validation stage. The requirements elicitation stage is considered as the foremost important stage of requirements engineering process, which is performed as a frontline activity to capture requirements from product users (Debnath, et al., 2020). The requirements elicitation team is internally comprised of two sub-teams/sub-groups including requirements analyst's team/group and product user's team/group.

In requirements elicitation, the requirements analyst's team and product user's team interact with each other using different requirements elicitation techniques to conceptualize anticipated product, (Díaz, et al., 2021). Traditionally, the requirements elicitation process is decomposed into four stages including objective establishment stage, background understanding stage, knowledge organization stage and requirements gathering stage (Lane, O'Raghallaigh, & Sammon, 2016). Consider the figure-1.3, which shows four stages of requirements elicitation process along with details of internal activities or tasks performed during each stage.

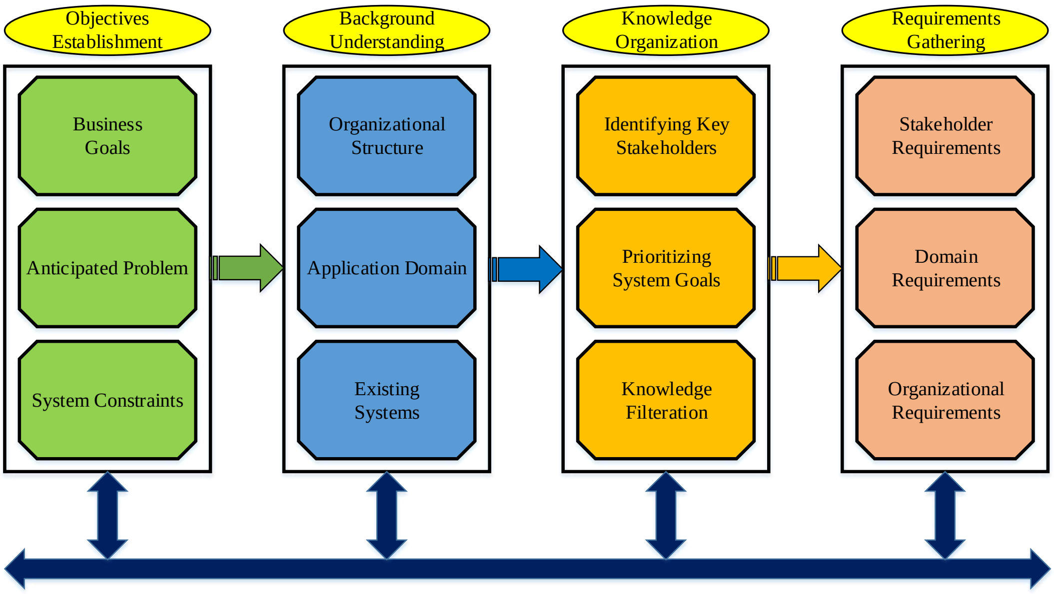
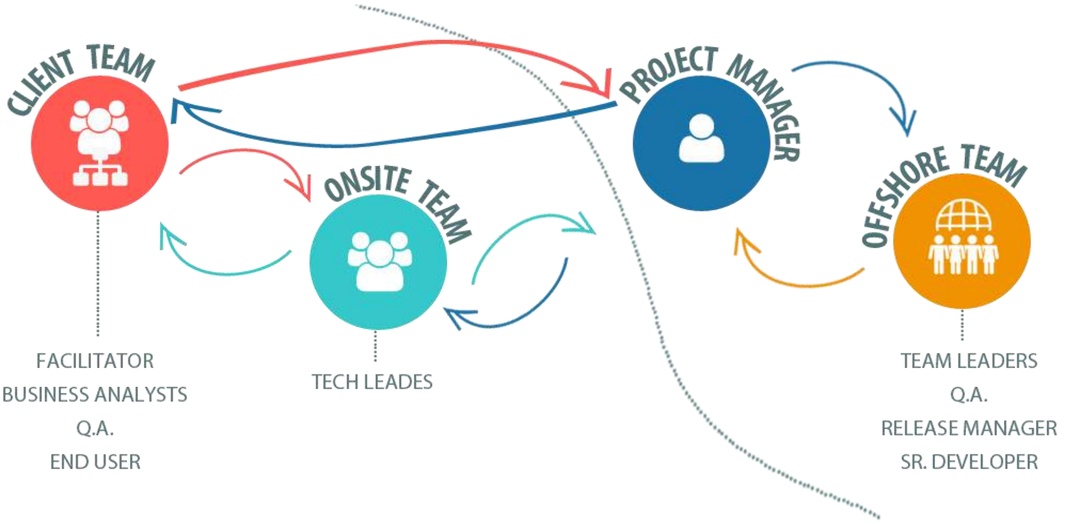


Figure-1.3: Requirements Elicitation Process (Lane et al., 2016)

1.1.3 Requirements Elicitation in Global Software Development

The *Global Software Development (GSD)* is also known as *Distributed Software Development (DSD)* where the software development teams are located in different parts of world and interact with each other using different communication technologies (Carrillo De Gea, Nicolás, Fernández-Alemán, & Toval, 2017). The global software development is motivated by the opportunities of reaching flexibility in resources, attaining extra knowledge, speeding-up time-to-market and growing operational efficiency (Saleem, 2019). The global software development has become a common practice in software industry where software development projects are geographically distributed across the different parts of world as is shown in figure-1.4. The software development teams working on GSD projects (commonly known as offshore projects) are distributed virtual teams as contrasted with traditional software development based on collocated physical teams working in the same locality (Ali & Lai, 2016). The global software development practice enables the software development companies to elevate their development quality (e.g. standards) as well as quantity (e.g. productivity) by collaborating their development efforts with other international companies (Khan, et al., 2021).



Source# http://www.dselva.co.in/offshore-software-development/

Figure-1.4: Global Software Development (Khan, et al., 2021)

The different software development task performed during subsequent stages of software development rationally become challenging in global software development projects due to their remote localization of team members (Khan, Malik, Chofreh, & Goni, 2017). The requirements elicitation task is considered as one of the most challenging task of software development in global software development environments due to its highly social and collaborative nature (Yaseen, Baseer, & Sherin, 2015). The requirements elicitation process in global software development contexts brings additional challenges for developers as compared to traditional software development contexts. The new challenges faced by requirements elicitation teams in GSD projects include the challenges occurred due to geographical distribution, temporal dispersion and cultural diversity of team members (Khan, Malik, Chofreh, & Goni, 2017), (Lim, et al., 2021).

Geographical Distribution factor of requirements elicitation in GSD introduces a big problem of lack of informal communication mechanisms due to the unavailability of face-to-face meetings. The informal communications are considered as the most important source of better understandability and information sharing in traditional requirements elicitation contexts (Nascimento, et al., 2020). The geographical distribution introduces anther big problem of lack of control and coordination during the requirements elicitation process. It becomes more difficult to manage globally distributed requirements elicitation teams as compared to collocated teams capable of freely interacting with each other at their times of interests and locations of comforts (Manjavacas, et al., 2020). The lack of control and coordination directly affects the quality of the elicitation process and subsequent outcomes in form of system requirements (Palomares, et al., 2021). The geographical distribution also introduces problem of work delays due to the poor communications, difficult coordination and lack of team mutual trust among team members.

Temporal Dispersion factor of requirements elicitation in GSD introduces additional challenges by limiting the time for interactions and communications among requirements elicitation team members. The asynchronous communication mostly becomes the option for interactions with team members due to the lack of time overlaps. The synchronous communication is always considered as the most feasible way of communication and information sharing as compared to asynchronous communication among team members (Palomares, et al., 2020). The requirements understandability also becomes very difficult in asynchronous communications that totally rely on the textual information shared between team members. The asynchronous communication totally relies on the sharing of information in textual form, which makes it very difficult for team members to share all information or ideas with complete details (Poth, et al., 2020).

Cultural Diversity factor of requirements elicitation in GSD introduces problems caused by cultural variations of distributed team members. The cultural variations of distributed teams create diversity in native languages, working attitudes, ethical norms, social norms, religious thoughts, personalities and governing scenarios. The cultural diversity becomes the main reason for the lack of trust among the distributed team members. Hence, the cultural diversity becomes major cause for the poor understandability of system information and user requirements due to the variations in native languages (hence poor understandability of common language) and working behaviors of participants (Rueda, et al., 2020), (Saeeda, et al., 2020).

1.1.4 User-Centricness in Requirements Elicitation

The user-centricness generally refers to the user-centered or user-oriented nature of a process where different tasks of the process are customized to facilitate the users of process (Peischl, Ferk, & Holzinger, 2014). Accordingly, the user-centricness in requirements elicitation process refers to the customization of whole elicitation process by using external parameters to facilitate the participating product users (user's team) during the elicitation sessions. The user-centricness can be achieved by using participant's hard-skills or soft-skills as external parameters to customize the whole requirements elicitation process (Brhel, Meth, Maedche, & Werder, 2015), (Ferrari, et al., 2020). The soft-skills based customizations may incorporate different human-factors like communication skills, inter-personal skills, work attitudes, work preferences and personality traits of participants (Giannakopoulou, et al., 2020), (Shojaifar, et al., 2020). The role of personality traits in the process of requirements elicitation becomes imperative due to the social and collaborative nature of this process where different people interact with each other to share system information (Costa, Reis, & Loureiro, 2015). Accordingly, the proposed framework has been incorporated with personality traits-based customizations of different internal activities and tasks in requirements elicitation process to achieve user-centricness.

The human factor plays a critical role in requirements elicitation process due to its collaborative and interactive nature to conceptualize the intimated product (Henriksson, et al., 2020), (Zalewski, et al., 2020). The requirements elicitation process is full of cross-sectional conversations among requirements analyst's team and other stakeholders of the product for conceptualization of intended product using different formal and informal communication mechanisms (Shafiq, et al., 2018). The requirements elicitation process is essentially a human-centered activity whose success is characteristically dependent on the working aptitude, work preferences, collaborative environment and behavioral capabilities of its involved participants. Therefore, the requirements elicitation process is essentially affected by the social, cultural and interpersonal aspects of its participants (Ambreen, Ikram, Usman, & Niazi, 2016).

The effective requirements elicitation leads to the finalization of high-quality requirements specifications which results in the development of the right product for right users (Hu, et al., 2020). The contextual analysis of requirements elicitation process reveals that composition of most appropriate requirements elicitation context plays a vital role in enhancement of the effectiveness of requirements elicitation process (Aldave, Vara, Granada, & Marcos, 2019). Consequently, the requirements elicitation process effectiveness is primarily dependent on the characteristics of requirements analyst's team, and product user's team that can be formulated from their personality traits (Kavallieratos, et al., 2020). Hence, there is a strong impact of user's team personality traits on the effectiveness of requirements elicitation process.

1.1.5 Personality Traits

The personality traits have a significant impact on individual's work aptitude, creativity, learning styles and intellectual capability (Chopik & Kitayama, 2017). The personality directly affects to individual's perception about their work aptitude and the social interactions with other members of community. The personality composition is a key indicator to determine the behavioral successfulness of an individual in his social circle and working groups (Parks-Leduc, Feldman, & Bardi, 2014). The personality traits generally refer to the characteristics of an individual, which contribute in his/her personal behaviors. There are different personality assessment models proposed by the researchers in the domain of psychology since last few decades. The most prominent personality assessment models that have been successfully used in the domain of psychology include the Five-Factor Model (FFM) commonly known as Big-Five personality assessment model (Stricker, Buecker, Schneider, & Preckel, 2019), the Myers-Briggs Type Indicator (MBTI) model (Cruz, Silva, & Capretz, 2015) and Kersey

Temperament Sorter (KTS) model (Yilmaz & Oconnor, 2015). The Myers-Briggs Type Indicator (MBTI) model and Big-Five personality assessment model have been successfully used in domain of software engineering since last few decades (Esmaeelinezhad & Afrazeh, 2018).

Big-Five Personality Model is considered as one of the most reliable personality assessment models extensively used in the domain of computer science and software engineering (Lotfi, Muktar, Ologbo, & Chiemeke, 2016). The big-five model classifies human personalities into five mega traits of openness, conscientiousness, extraversion, agreeableness and neuroticism. The big-five model classification of humans into five mega traits is globally accepted classification, which merge many other personality assessment models and is shown in the figure-1.5.

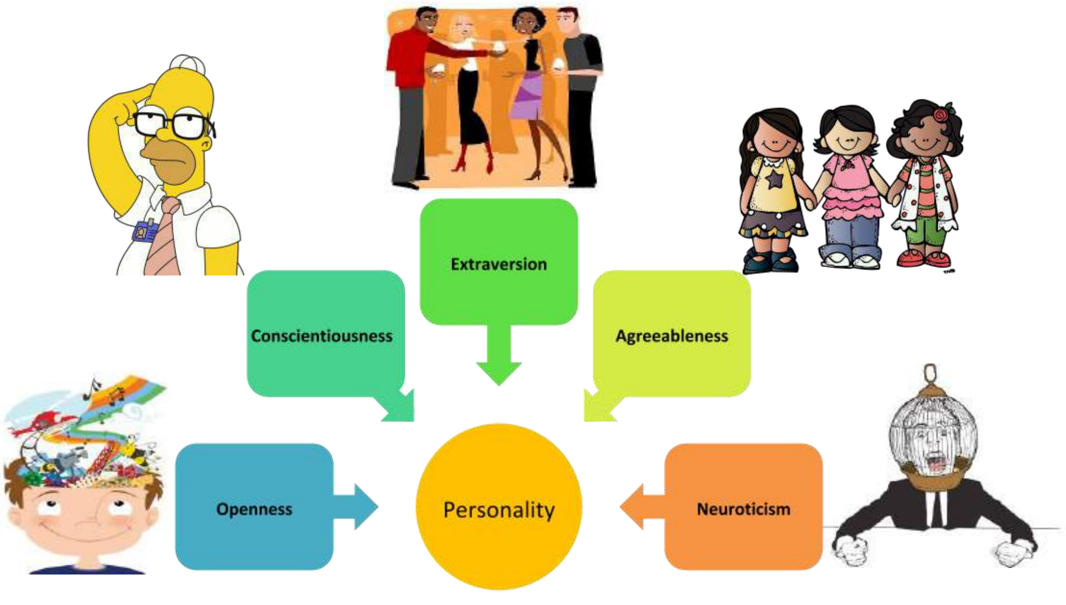


Figure-1.5: Big-Five Personality Traits (Yilmaz et al., 2017)

The big-five personality traits are commonly known as OCEAN to represent the openness, conscientiousness, extraversion, agreeableness and neuroticism (Yilmaz, O'Connor & Clarke, 2017). The ***openness*** to experience represents inquisitiveness about new ideas, values, feelings and interests. The ***conscientiousness*** is a trait of perseverant, scrupulous and responsible behavior. The ***extroversion*** is a trait of people who take a trusting and enthusiastic view of others, which is associated with being sociable, assertive and talkative. The ***agreeableness*** is a trait of showing altruistic concern and emotional support towards other people. The ***neuroticism*** is a broad dimension that includes traits like anxiety, moodiness, irritability or frustration.

Consider the figure-1.6, which shows the low and high attributes of big-five traits by choosing three most recommended characteristics. The high attributes of openness include perceptual dysregulation, eccentricity and magical thinking while the low attributes of openness include derivative, inflexible and closed mindedness (Yilmaz, O'Connor & Clarke, 2017). The high attributes of conscientiousness include workaholics, perfectionism and being organized while the low attributes of conscientiousness include irresponsibility, distractibility and rashness (Yilmaz, O'Connor & Clarke, 2017). The high attributes of extraversion include attention seeking, talkative and excitement seeking while the low attributes of extraversion include social withdrawal, detached coldness and anhedonia (Yilmaz, O'Connor & Clarke, 2017).

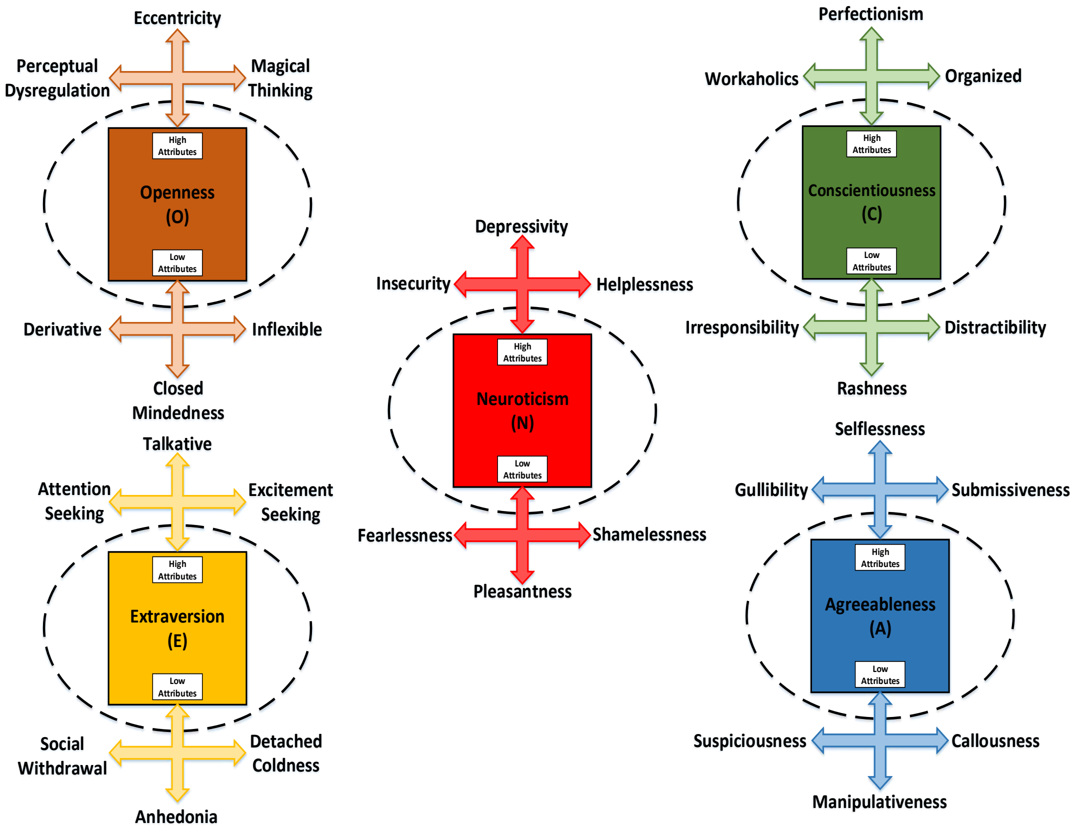


Figure-1.6: High and Low Attributes of Big-Five Traits (Yilmaz et al., 2017)

The high attributes of agreeableness include gullibility, selflessness and submissiveness while the low attributes of agreeableness include suspiciousness, callousness and manipulativeness (Yilmaz, O'Connor & Clarke, 2017). The high attributes of neuroticism include insecurity, expressivity and helplessness while the low attributes of neuroticism include fearlessness, shamelessness and pleasantness (Yilmaz, O'Connor & Clarke, 2017). The different characteristics of each big-five trait are derivatives of each other and can be associate with each other. Hence, a comprehensive list of major characteristics of each big-five trait can be drawn in the form of a table to represent the trait aptitudes (Jia, Zhang, & Zhang, 2015). Consider the table-1.1, which shows the most prominent characteristics of big-five personality traits including openness, conscientiousness, extraversion, agreeableness and neuroticism (Yilmaz, O'Connor &

Clarke, 2017), (Anwar, 2017), (Church, 2016). These personality characteristics can be used for the evaluation and recognition of the personality of any person.

Table-1.1: Major Characteristics of Big-Five Traits

Big-Five Trait	Major Characteristics of Trait
Openness (O)	Intelligent, Adventurous, Curious, Imaginative, Explorative, Creative, Unusual Ideas, Intellectual, Analytical
Conscientiousness (C)	Organized, Responsible, Hardworking, Punctual, Practical, Serious, Reliable, Competent, Achievement Striving
Extraversion (E)	Talkative, Outgoing, Assertive, Compelling, Sociable, Energetic, Outspoken, Ambitious, Dominant, Forceful
Agreeableness (A)	Cooperative, Unselfish, Helpful, Caring, Sympathetic, Friendly, Warm, Modesty
Neuroticism (N)	Anxious, Worried, Envied, Feared, Frustrated, Tense, Depress, Impulsive, Angry, Emotionally Instable

1.2 STATEMENT OF THE PROBLEM

The requirements elicitation is considered as the foremost important phase of the requirements engineering during the software development lifecycle with ultimate goal of gathering requirements of product (Burnay, et al., 2020). Usually, the requirements elicitation process is full of cross-sectional conversations using formal and informal communications and frequent interactions among key stakeholders of the product for conceptualization of intended product (Cirqueira, et al., 2020). The social and collaborative nature of requirements elicitation process baselines its primary dependence on human-factors like behavior, styles/patterns, preferences and personality traits of its participants (requirements engineers and product users) during traditional in-house software development as well as modern global software development context (Dar, et al., 2020). Accordingly, the user personality traits have a great influence on the overall process of requirements elicitation for global software development teams due to the inherited social and cultural diversity of involved participants (Debnath, et al., 2020). The state-of-art research so far available on requirements elicitation process for global software development contexts has primarily focused the role of human factors like behaviors, styles, patterns, preferences and ethics (Díaz, et al., 2021). There is no significant work available on the customization of requirements elicitation process to make it user-centric using human factors of personality traits of requirements elicitation stakeholders like product users. Hence, there is a serious need to devise a *User-Centric Requirements Elicitation Framework for Global Software Development Teams (UCRE Framework for GSD Teams)* which should incorporate user's personality traits along with other concerned factors. This framework will serve as an asset for project managers and company heads to better plan the configuration of requirements elicitation teams and elicitation context by looking at the personality traits of product users.

1.3 RESEARCH OBJECTIVES

The research for development of the proposed user-centric requirements elicitation framework for global software development teams is assumed to meet the following research objectives:

Research Objective-1:

To investigate the main influencing factors on which the requirements elicitation process depends for global software development teams?

Research Objective-2:

To investigate the effect of user's personality traits on the requirements elicitation process for global software development teams?

Research Objective-3:

To investigate the effect of user-centricness on the requirements elicitation process for global software development teams?

Research Objective-4:

To develop user-centric requirements elicitation framework based on user's personality traits for global software development teams?

Research Objective-5:

To evaluate user-centric requirements elicitation framework based on user's personality traits for global software development teams?

1.4 RESEARCH QUESTIONS

The research for development of the proposed user-centric requirements elicitation framework for global software development teams is carried out to find the answers of the following research questions:

1.4.1 Main Research Question

The goal of this research is to devise a user-centric framework to improve the requirements elicitation process for global software development teams. Given this goal, the main research question for investigation becomes as under:

Can we incorporate the user's personality traits along with other associated factors in the requirements elicitation frameworks to improve the elicitation process for global software development teams?

1.4.2 Specific Research Questions

The main research question is further decomposed into following set of more specific research questions to define the research layout in a systematic way:

Research Question-1:

What are the main influencing factors on which the requirements elicitation process depends for global software development teams?

Research Question-2:

How the user's personality traits can affect the requirements elicitation process for global software development teams?

Research Question-3:

How the user-centricness can affect the requirements elicitation process for global software development teams?

Research Question-4:

How the user-centric requirements elicitation framework based on user's personality traits can be developed for global software development teams?

Research Question-5:

How user-centric requirements elicitation framework based on user's personality traits can be evaluated for global software development teams?

1.5 RESEARCH HYPOTHESIS

The following set of research hypothesis is formulated from the research questions to investigate the development of proposed user-centric requirements elicitation framework for global software development teams:

Main Hypothesis:

The user-centricness based on user's personality traits have influence on requirements elicitation frameworks for global software development teams.

Alternative Hypothesis-1 (H_1):

The user's personality traits generally influence the requirements elicitation process for global software development teams.

Alternative Hypothesis-2 (H_2):

The user-centricness based on user's personality traits more specifically influence the requirements elicitation process for global software development teams.

Alternative Hypothesis-3 (H_3):

The user-centric frameworks based on user's personality traits positively contribute in the improvement of requirements elicitation process for global software development teams.

1.6 PURPOSE OF THE STUDY

The main purpose of this study is to improve the requirements elicitation process for global software development teams. The anticipated improvement has been carried-out by proposing user-centric requirements elicitation framework incorporated with user's personality traits for selecting the most suitable requirements elicitation teams, requirements elicitation techniques and requirements elicitation groupware tools. The inclusion of user's personality traits in recruitment of requirements elicitation teams would benefit software development companies to better plan their elicitation contexts and select most suitable team members who can proactively contribute in the improvement of requirements elicitation. It is evident from literature and industry practice that requirements elicitation process becomes more challenging for software development teams working in globally distributed environments as compared to traditional in-house software development teams (working in the same locality) due to its highly social and collaborative context.

Therefore, the proposed requirements elicitation framework would be equally applicable and beneficial for traditional in-house software development teams with recommended minor customizations in its contextual parameters. This customization would enable software industry to use the proposed framework as a valuable asset that would serve as a requirements elicitation team selection tool/technology for global software development teams. The proposed requirements elicitation framework can be integrated in requirements elicitation tools/technologies used by software development industry to improve the overall elicitation context by engaging elicitation sessions with product users/stakeholders using most suitable elicitation teams, techniques and tools.

1.7 SIGNIFICANCE OF THE STUDY

The main concern of this research is to provide a user-centric requirements elicitation framework, which is incorporated with user's personality traits (along with other relevant factors of RE-GSD) for global software development teams. The envisioned user-centric framework is expected to provide an improved mechanism for requirements elicitation process for those environments where software development teams as-well-as product users are geographically distributed in different parts of world. The interactions between software development teams and product users become a more challenging task in offshore projects due to the variations in geological locations, time zones, languages and culture of participants as compared to traditional in-house software development contexts. The proposed requirements elicitation framework will help the software development industry in the following aspects:

1. The proposed framework will help the software industry to understand the impact/effect of user-centricness on requirements elicitation process for global software development teams.

2. The proposed framework will help the software industry to understand the general impact/effect of personality traits factor on requirements elicitation process for global software development teams.

3. The proposed framework will help the software industry to understand the specific impact/effect of user's personality traits on requirements elicitation process for global software development teams.

4. The proposed framework will contribute in improvement of software development process by improving overall requirements elicitation process for global software development teams.

5. The proposed framework will serve as an asset for software industry to better plan the most effective/productive requirements elicitation contexts for global software development teams.

1.8 LIMITATIONS OF THE STUDY

The following limitations of this research have been appraised during the development and evaluation process of the proposed framework.

1.8.1 Framework Extension for Other Personality Models

The proposed framework is incorporated with big-five personality assessment model due to its wide acceptance in the domain of software engineering. The results of the proposed framework are encouraging for the global software development context when incorporated with big-five personality assessment model. There are two other personality assessment models including Myers-Briggs Type Indicator (MBTI) and Keirsey Temperament Sorter (KTS), which have been adopted by researchers in domain of software engineering. The big-five personality assessment model is more generic models but proposed framework can be incorporated with these two models to observe the variations in the generated results. It is also possible to incorporate both of these personality assessment models in the proposed framework along with big-five personality assessment model to observe the collective effect of these models on the generated outputs.

1.8.2 Framework Evaluation for Other Types of Software Industries

The proposed framework has been evaluated at industrial scale by using requirements elicitation team's distribution patterns only. Three types of software companies have been used during industrial evaluation of the proposed framework including low, medium and high geographical distributions in requirements elicitation teams. Hence, the requirements elicitation team distribution has been used to select the software development companies irrespective of their sizes. The framework evaluation can further be extended by considering the companies of different sizes like small sized companies, medium sized companies and large sized companies to observe the impact on the generated output due to the variations in requirements elicitation team sizes.

1.8.3 Framework Customizations for Non-GSD Contexts

The proposed framework can be customized for traditional software development contexts by removing the globalization factors involved due to the variations in the geological localities of the team members. This type of framework customization will enable us to observe the sole impact of situational factors on the generated outputs irrespective of any globalization factor. This customization will also enable us to observe the impacts on generated outputs due to the mutual relations of the situational factors and globalization factors.

1.8.4 Framework Considerations for Participants Preferences

The proposed framework is incorporated with analyst preferences and user preferences as simple choice for requirements elicitation techniques and groupware tools. The proposed framework can also be incorporated with true preferences of analyst team and user team in terms of time preference, style preference, resource preference, context preference, communication type preference, language preference and work pattern preference etc.

1.8.5 Framework Automation in Groupware Tools

The proposed framework evaluation has been carried out without its integration in any available groupware tools used by global software development teams working on actual offshore projects. The evaluation process was carried out at small-scale (pilot test) and full-scale (industrial test) using standard evaluation templates provided by IEEE for SRS documentation and NEO-IPIP standard inventory for personality assessment. The integration of proposed framework would enable us to observe its real time performance using actual interacting tools and technologies used in global software development context.

1.9 DEFINITIONS OF THE TERMS

The following paragraphs present the definitions of the specific terms that have been used in the thesis with appropriate explanation. The usage context of each specific term is also explained where it was appropriate and desirous to completely understand the context and meanings of each term.

User

The term *"**User**"* here refers to informant or informer in the process of requirements elicitation. The stakeholders in requirements elicitation process generally include requirements analyst/engineer team and user team. In the elicitation process, the analyst team elicits requirements from the user team. Here, the user team members are referred as Users. Therefore, Users refers to those persons from whom requirements analyst team elicits requirements.

Stakeholders

The term *"**Stakeholders**"* refers to the participants of requirements elicitation process. Generally, the requirements elicitation process involves two types of stakeholders including requirements analyst/engineer team members and user team members.

User-Centric

The term *"**User-Centric**"* means user centered, user oriented or user customizable. This term is used in the document to show that the process is user oriented in way that each step or computation performed in the process is more facilitating for user.

Personality Traits

The term *"**Personality Traits**"* refers to the human classification schemes based on their behavioral characteristics. The different personality traits assessment models include Big-Five model, Myers-Briggs Type Indicator (MBTI) model and Keirsey Temperament Sorter (KTS) model etc. The MBTI model and Big-Five model have been extensively used in the domain of computer science and software engineering for the personality assessment of different roles since last few decades.

Global Software Development

The term *"**Global Software Development**"* refers to the industry practice of software development where software development teams are physically located in different parts of the world. These teams interact with each other using internet-based communication tools and technologies existing in the form of synchronous and asynchronous tools.

Traditional Software Development

The term *"**Traditional Software Development**"* refers to the industry practice of software development where software development teams are physically located in same location and is also known as in-house software development.

Offshore Projects

The term *"**Offshore Projects**"* refers to those software development projects, which are implemented by software development companies physically located in other countries of world as compared to project hosting organization.

Outsource Projects

The term *"**Outsource Projects**"* refers to those projects, which are sub-contracted by an organization to some other organization for their development. Generally, large sized projects are sub-contracted as outsource projects to other organizations.

Virtual Teams

The term *"**Virtual Teams**"* refers to software development teams, which are physically located in different localities. The global software development teams are known as virtual teams.

Globalization Factors

The term *"**Globalization Factors**"* refers to those factors, which are concerned with geographical context of any process or activity. The globalization factors may include geographical distribution, temporal dispersion, cultural diversity, knowledge management, team's trust and coordination and control.

Situational Factors

The term *"**Situational Factors**"* refers to those factors, which are concerned with situational context of any process or activity. The situational factors may include organizational factors, stakeholder factors, project factors, process factors and product factors.

Human Factors

The term *"**Human Factors**"* refers to those factors, which are human based or human oriented. The human factors may include human attitudes, norms, preferences, priorities, personality and culture.

Geographical Distribution

The term *"**Geographical Distribution**"* refers to the variations in the physical locality of the people belonging to different countries of the world. The global software development teams are composed of people with difference in their physical localities.

Temporal Dispersion

The term *"**Temporal Dispersion**"* refers to the difference or variation in the time zones of different regions of the world. The global software development teams are composed of people having difference in their time zones.

Cultural Diversity

The term *"**Cultural Diversity**"* refers to the variations in cultures of different regions of world. The global software development teams are composed of people having diversity in their cultures.

1.10 LIST OF ABBREVIATIONS

In the following paragraph, the list of abbreviations is provided to better understand the terms and terminologies used in the thesis.

ACM: Association for Computing Machinery

ANA: Analytical

BSCS: Bachelors of Science in Computer Science

BSSE: Bachelors of Science in Software Engineering

CON: Conversational

CS: Computer Science

DAF: Data Analysis Forms

ESS: Essential Soft Skills

FFM: Five Factor Model

FS: Felder-Silverman

GMT: Greenwich Mean Time

GSD: Global Software Development

GTNE: Groupware Tools Net Effectiveness

IEEE: Institute of Electrical and Electronics Engineers

IPIP: International Personality Item Pool

IT: Information Technology

JAD: Joint Application Development

JD: Job Description

KTS: kerseys Temperament Sorter

MBTI: Myers Briggs Type Indicator

NEO: Neuroticism, Extraversion & Openness

NSF: Net Support Factor

OBS: Observational

OCEAN: Openness, Conscientiousness, Extroversion, Agreeableness, Neuroticism

PAF: Personality Assessment Form

PIF: Personal/Project Information Form

PQF: Personality Questionnaire Form

RE: Requirements Engineering

RE-GSD: Requirements Engineering in GSD

RAD: Rapid Application Development

RCF: Requirements Collection Form

REF: Requirements Evaluation Form

SC: Software Company

SE: Software Engineering

SF: Support Factor

SGT: Selected Groupware Tool

SIF: Stakeholders Information Form

SLR: Systematic Literature Review

SRS: Software Requirements Specifications

SYN: Synthetic

TCF: Team Characteristics Form

TEF: Trainings Evaluation Form

UCRE: User-Centric Requirements Elicitation

WIF: Work Information Form

1.11 CHAPTER SUMMARY

The social and cultural context of requirements elicitation process in global software development baselines its primary dependence on human-factors like behavior, styles/patterns, preferences and personality traits of its participants. The personality traits of participants of requirements elicitation process (i.e. requirements engineering team and product users) play a vital role in the successful execution of this process with improved quality of generated outcomes. The user personality traits play a vital role in socially collaborative and interactive information sharing activities performed during requirements elicitation process. The impact of user personality traits on requirements elicitation process further increases when the development teams as well as product users are geologically distributed at variant offshore places across the globe. The diversity in geological locations of participants becomes the main cause of variations in their cultural norms and work attitudes during requirements elicitation process. The cultural diversity directly affects the working attitudes, personality traits and work preferences of participants in requirements elicitation process for global software development teams. In this regard, a user-centric requirements elicitation framework is proposed to support requirements elicitation process in global software development teams to improve the elicitation context and its subsequent outcomes.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents a comprehensive literature review about the research studies conducted on requirements elicitation process in global software development environments. The chapter includes a detailed review of studies published in international journals and conferences of good repute during last two decades (2000 to 2020). The literature review includes only research articles published in indexed journals and conferences to present the most trustworthy research literature available on the *Requirements Elicitation in Global Software Development (RE-GSD).*

Theoretical Review introduces the general perspective of requirements engineering process for global software development environments and introduces the particular role of requirements elicitation in distributed contexts. The theoretical review includes research studies conducted on different improvement aspects of requirements elicitation process in global software development contexts.

2.1 INTRODUCTION

The requirements elicitation process is considered as the most imperative process of requirements engineering during the software development life cycle activities (Niknafs & Berry, 2016). The eventual goal of requirements elicitation process is to elicit/gather the requirements of the intended software product from the customer. The requirements elicitation process is considered as the most social and collaborative activity full of cross-sectional conversations among participants using different communication mechanisms (Lane, O'Raghallaigh, & Sammon, 2016). Accordingly, the requirements elicitation process is considered as the most human-centric process based on frequent interactions and collaborations of participants using different conversational techniques. The literature studies and the industry practices revealed the critical dependability of requirements elicitation process on the face-to-face communication using informal mechanisms (Anwar & Razali, 2016). The requirements elicitation process becomes even more challenging for projects where the participants are remotely located and use technology-based communication tools to perform different conversations. Therefore, the requirements elicitation process in globally distributed software development teams introduces new challenges relating to information sharing and process coordination as compared to traditional collocated elicitation scenarios (Ali, & Lai, 2018).

2.2 GLOBAL SOFTWARE DEVELOPMENT

The *Global Software Development (GSD)* has become a modern trend for software development industry since last few decades where software projects are outsourced to other companies to finish product with larger pool of resources (Calefato, Damian, & Lanubile, 2011). The global software development is inspired by the opportunities of speeding up time to market, reaching mobility in resources, accessing more skilled and cheaper labour and increasing operational efficiency. The global software development is accompanied by many attractions along with additional development challenges as compared to traditional software development (Anwar & Razali, 2016). The global software development widens the notion of traditional outsourcing and addresses evolution of traditional in-house software development to a more complex scenario of disseminating work among development teams fragmented by various boundaries, such as contextual and organizational variations, geographical distribution, temporal dispersion, cultural diversity and political diversity (Brockmann & Thaumuller, 2009). Therefore, the global software development context can be characterized by its structural heterogeneity, resource verticalness, inter-organizational communication and work collaboration, which become major obstacles for effective communication and cooperation among teams involved in completion of a joint venture (Calefato, Damian, & Lanubile, 2011). The perception of global software development enabled the software industry to collaborate with culturally diverse international brands of software development to opt better opportunities of product development (Damian, 2007).

2.3 REQUIREMENTS ELICITATION IN GSD

The requirements elicitation process is full of cross-sectional conversations between software development teams and product users. The nature of requirements elicitation process makes it a more social and cultural process rather than a traditional computing or engineering work of software development (Aranda, Dieste, & Juristo, 2016). Hence, the nature of requirements elicitation process declares it as a human-centered activity, which critically depends upon the soft skills of participants (Calefato, Damian, & Lanubile, 2011). The interactions and collaborations of participants become a vital tool of success in requirements elicitation process in traditional software development contexts as well as global software development contexts (Lescher, 2009). The requirements elicitation process becomes more challenging for projects where the participants are remotely located and use communication tools to perform different conversations. Therefore, the requirements elicitation process in globally distributed software development teams introduces new challenges relating to information sharing and process coordination as compared to traditional collocated elicitation scenarios (Lohmann, Ziegler, & Heim, 2008).

Empirical Review of literature includes research studies that have been conducted on *Requirements Elicitation in Global Software Development (RE-GSD)* and have highlighted different challenges and suggested possible solutions/strategies in form of guidelines, factors, technologies, processes, methodologies, models and frameworks. The studies presented in empirical review have been classified into five major categories according to their contributions for RE-GSD context. The different categories include (1) studies on challenges and strategies in RE-GSD, (2) studies on situational factors in RE-GSD, (3) studies on groupware technologies in RE-GSD, (4) studies on processes and methodologies in RE-GSD (5) studies on models and frameworks in RE-GSD.

2.4 STUDIES ON CHALLENGES AND STRATEGIES IN RE-GSD

This section includes those studies, which presented works on challenges, problems and issues faced by software industry during requirements elicitation process for global software development environments. Only those research studies have been included in this section, which have been published in international journals and conferences of good repute since last two decades. Consider the table 2.1, which presents the complete empirical data of presented articles of this section.

Table 2.1 Studies on Challenges and Strategies in RE-GSD: Empirical Review

Article	Author	Publishing	Sample	Methods	Contributions
2.4.1	Muhammad Yaseen et al.	IEEE Conference Article (2015)	None	Systematic Literature Review (SLR)	Highlighted Critical Challenges of RE in GSD
2.4.2	Nabiha Usmani et al.	Journal Article (2017)	Software Industry	Survey	Discussed Different GSD Challenges

2.4.3	Klaus Schmid	Springer Conference Article (2014)	Software Industry	Traditional Literature Review, Survey	Highlighted Challenges and Solutions of RE-GSD
2.4.4	Ishtiaq Hussain et al.	Journal Article (2012)	None	Traditional Literature Review	Highlighted Social, Cultural and Cognitive Issues of RE in GSD Projects
2.4.5	Muhammad Azeem Akbar et al.	IEEE Journal Article (2020)	79 Software Industry Experts	Survey, Systematic Mapping Study	Identified twenty different barriers for RE process in GSD Context
2.4.6	Alejandro Lopez et al.	IEEE Conference Article (2009)	None	Systematic Literature Review (SLR)	Discussed different risks safeguards for RE process in GSD projects
2.4.7	Hanisch Jo et al.	Journal Article (2007)	Software Industry	Structured Interviews, Case Study	Highlighted communication impediments for RE-GSD
2.4.8	Hanisch, Jo et al.	Conference Article (2004)	Software Industry	Case Study	Discussed communication issues as impediment for RE-GSD
2.4.9	Daniela E. Damian et al.	Springer Journal Article (2003)	Twenty-four Stakeholders	Case Study, Industrial Survey	Highlighted RE challenges for distributed stakeholders
2.4.10	Jyoti M. Bhat et al.	IEEE Software Journal Article (2006)	None	Literature Review, Case Study	Presented guidelines to overcome RE challenges in offshore projects
2.4.11	Daniela E. Damian et al.	IEEE Conference Article (2002)	Software Industry	Case Study, Industrial Survey	Highlighted impact of stakeholder’s distribution in multi-site RE

Summary of Contributions

The studies presented in this section, highlighted different problems or issues or challenges or barriers faced by software engineers while performing requirements elicitation work in global software development projects. The majority of these studies also talked about the possible solutions/strategies to manage or improve these challenges. The majority of the challenges highlighted emerge from the main hurdles of geographical distribution, temporal dispersion, cultural diversity, communication issues, knowledge management issues, control and coordination related issues and inappropriate communication and collaboration technologies-based issues.

2.4.1 Muhammad Yaseen et al. (2015) highlighted different challenges and barriers in requirements elicitation process in global software development context. The authors performed a systematic literature review to analyze different factors that may affect negatively to the performance and quality of requirements elicitation process in global software development projects.

2.4.2 Nabiha Usmani et al. (2017) performed an industry survey to list down major challenges and issues faced by software professionals during the requirements elicitation process in global software development context. The authors categorized different challenging factors that may affect the requirements elicitation process in distributed software development teams.

2.4.3 Klaus Schmid (2014) presented a survey about the different challenges and their corresponding solutions for requirements elicitation process in globally distributed software development environments. The authors addressed both the development of systems for internationally distributed software clients and situation of global requirements engineering in global software development projects.

2.4.4 Ishtiaq Hussain et al. (2012) presented a literature review and an industrial survey to highlight the major communication related challenges faced by software development teams during requirements elicitation process in globally distributed software development teams. The authors also proposed a set of strategies and solutions that might help developers to manage communication related challenges of requirements elicitation in GSD context.

2.4.5 Muhammad Azeem Akbar et al. (2020) presented a systematic study to highlight the main challenges and procedural issues of requirements engineering process faced by developers in global software development environments. The authors presented list of twenty mega barriers/challenges of requirements engineering process and provided guidelines to improve the requirements engineering process for the global software development domain.

2.4.6 Alejandro Lopez et al. (2009) performed a systematic literature review and highlighted a set of potential risks, which become hurdle for requirements engineering activities in global software development projects. The authors also suggested a set of possible safeguards that might help the developers to minimize the effects of potential risks for requirements engineering process in GSD context.

2.4.7 Hanisch Jo et al. (2007) interviewed software developers from a globally distributed software development team and performed an analysis to formulate a comprehensive list of impediments of requirements engineering process in global software development environments. The authors investigated the communication related impediments that become source of misunderstandings among team members due to diversity in cultural and social norms of participants.

2.4.8 Hanisch, Jo et al. (2004) presented a case study about a distributed software development project completed between teams sitting in two different countries and online collaborated for requirements elicitation process. The authors nominated communication as the one of the main challenging impediments during requirements engineering activities performed in distributed software development projects.

2.4.9 Daniela E. Damian et al. (2003) presented a comprehensive field study about requirements engineering challenges using a case study about software development in multi-site organizations. The authors highlighted the main challenges of requirements engineering process in distributed environments due to geographical distribution, temporal dispersion, cultural diversity and linguistic diversity.

2.4.10 Jyoti M. Bhat et al. (2006) presented a study about the major challenges faced by requirements engineering teams in offshore outsource projects and suggested strategies to overcome these challenges. The authors performed literature review and run an industrial case study to validate the presented requirements engineering challenges and their corresponding countering strategies.

2.4.11 Daniela E. Damian et al. (2002) presented an industrial case study and questionnaire survey to highlight the impact of stakeholder's geographical distribution on the requirements elicitation process running in multi-site software development organizations. The authors discussed how multi-site communication and knowledge management affects the requirements gathering process along with cultural diversity and temporal dispersion.

2.5 STUDIES ON SITUATIONAL FACTORS IN RE-GSD

This section includes those studies, which presented works on situational and environmental factors involved during requirements elicitation process for global software development environments. Only those research studies have been included in this section, which have been published in international journals and conferences of good repute since last two decades. Consider the table 2.2, which presents the complete empirical data of presented articles of this section.

Table 2.2 Studies on Situational Factors in RE-GSD: Empirical Review

Article	Author	Publishing	Sample	Methods	Contributions
2.5.1	Huma Hayat Khan et al.	Springer Conference Article (2018)	None	Systematic Literature Review (SLR)	Highlighted Situational Contexts in RE-GSD
2.5.2	Huma Hayat Khan et al.	IEEE Conference Article (2013)	None	Systematic Literature Review (SLR) Protocol	Provided SLR Protocol to Combine Situational Reworks in GSD
2.5.3	Huma Hayat Khan et al.	IEEE Conference Article (2013)	None	Systematic Literature Review (SLR)	Compiled a List of Situational Factors Affecting reworks in GSD
2.5.4	Huma Hayat Khan et al.	Conference Article (2013)	None	Systematic Literature Review	Identified Risk Generating Factors for RE-GSD
2.5.5	Huma Hayat Khan et al.	Journal Article (2014)	None	Systematic Literature Review	Identified Risk Generating Factors for RE-GSD

2.5.6	Huma Hayat Khan et al.	Journal Article (2014)	None	Systematic Literature Review (SLR)	Identified Situational Factors for RE-GSD from SE Standards
2.5.7	Omid Jafarinezhad et al.	ACM Conference Article 2012	None	Literature Review	Provide a feature-based RE process factory to develop RE processes
2.5.8	Omid Jafarinezhad et al.	IEEE Conference Article (2012)	None	Literature Review	Provided a feature-based RE process factory to develop RE processes
2.5.9	Chad Coulin et al.	John Wiley & Sons Journal Article (2006)	Software Industry	Survey Method	Presented a systematic early RE situational method
2.5.10	R´egine Laleau	John Wiley & Sons Journal Article (2006)	Software Industry	Survey Method	defined RE method based on situational engineering methodology

Summary of Contributions

The studies presented in this section highlighted different environmental, situational, or contextual factors affecting the requirements elicitation process in global software development environments. The authors commonly used simple literature review or systematic literature review methodology to collect information about such type of factors from already published literature and used traditional questionnaire-based survey methodology to validate these factors from researchers working in academia and/or industry.

2.5.1 Huma Hayat Khan et al. (2018) reviewed the existing situational requirements engineering frameworks and highlighted a list of twelve situational contexts including organizational context, stakeholder context, requirements context, project context, management context, risk context, cultural context, standard context, task context, communicational context, techniques and methods context and innovation context.

2.5.2 Huma Hayat Khan et al. (2013) presented a systematic literature review protocol to facilitate the process of combing situational requirements engineering work with global software development environments. The authors also provided a checklist of situational characteristics that can be incorporate with global software development practices.

2.5.3 Huma Hayat Khan et al. (2013) compiled a list of situational factors affecting the requirements engineering process in global software development projects. The authors formulated an initial list of 37 situational factors that directly or indirectly affect the requirements engineering tasks in global software development contexts.

2.5.4 Huma Hayat Khan et al. (2013) identified a comprehensive list of risks generation factors (situational factors) for requirements engineering in global software development environments. The authors highlighted that identified risks generation factors may create difficulties for software developers during requirements engineering practices in GSD projects.

2.5.5 Huma Hayat Khan et al. (2014) identified a list of risks generation factors (situational factors) and consequent risks for requirements engineering process running in global software development projects. The authors highlighted that identified risks generation factors and consequently identified risks may create difficulties for software developers during requirements engineering practices.

2.5.6 Huma Hayat Khan et al. (2014) identified a preliminary list of situational factors using grounded theory from domain of standards and models for requirements engineering practice in GSD projects. The authors formulated a set of key factors that may negatively affect the requirements engineering process in GSD projects due to the change in the situational context of project.

2.5.7 Omid Jafarinezhad et al. (2012) presented a mapping for translating the situation model to the RE process feature model is proposed with the specific aim of promoting traceability and rationality in the selection of requirements engineering process features.

2.5.8 Omid Jafarinezhad et al. (2012) presented a mapping for translating the situation model to the RE process feature model with the specific aim of promoting traceability and rationality in the selection of RE process features. The efficacy of the approach is demonstrated through a RE process development example.

2.5.9 Chad Coulin et al. (2006) provided practitioners with an approach to requirements elicitation that can be readily applied to real-world projects in order to improve both the process and the results. The work also offers researchers an example of how lightweight situational method engineering can be applied to very practical activities and situations in the software process.

2.5.10 R´egine Laleau et al. (2006) presented a method in which during the first step of the project, properties were extracted from standards written in natural language and a conceptual model of the underlying system was elaborated. Since none of the existing requirements engineering methods were able to consider the specifics of their project, they turned to situational method engineering, and have defined a new RE method based on this approach.

2.6 STUDIES ON GROUPWARE TECHNOLOGIES IN RE-GSD

This section includes those studies, which presented works on groupware tools and technologies used by software industry during requirements elicitation process for global software development environments. Only those research studies have been included in this section, which have been published in international journals and conferences of good repute since last two decades. Consider the table 2.3, which presents the complete empirical data of presented articles of this section.

Table 2.3 Studies on Groupware Technologies in RE-GSD: Empirical Review

Article	Author	Publishing	Sample	Methods	Contributions
2.6.1	Somnoup Yos et al.	Conference Article (2018)	None	Feature Analysis Screening Mode	Highlighted the ways to use tools to solve RE-GSD challenges
2.6.2	Carlos Solis et al.	IEEE Conference Article (2010)	None	Literature Review	Recommended hypertext wiki as collaboration tool for RE-GSD
2.6.3	Juan Manuel Carrillo de Gea et al.	John Wiley & Sons Journal Article (2017)	Software Industry	Industrial Survey	Highlighted a set of features for groupware tools for RE-GSD
2.6.4	Gabriela N. Aranda et al.	Springer Conference Article (2010)	SE Students	Case Study, Controlled Experiment	Presented a set of strategies to recommend groupware tools
2.6.5	Gabriela N. Aranda et al.	IEEE Conference Article (2009)	SE Students	Controlled Experiment	Presented a method to select groupware tool
2.6.6	Gabriela N. Aranda et al.	Springer Conference Article (2009)	SE Students	Controlled Experiment	Presented analysis on stakeholder's satisfactions on groupware tools

2.6.7	Gabriela N. Aranda et al.	IEEE Conference Article (2008)	SE Students	Controlled Experiment	Presented strategies to select groupware tools using team characteristics
2.6.8	Gabriela N. Aranda et al.	Springer Conference Article (2007)	Software Industry	Survey	Proposed an approach to select suitable groupware tool
2.6.9	Gabriela N. Aranda et al.	IEEE Conference Article (2006)	Software Industry	Literature Review, Survey	Presented an approach to use cognitive styles to select groupware tools
2.6.10	Gabriela N. Aranda et al.	Conference Article (2005)	Software Industry	Literature Review, Survey	Presented a method to select elicitation techniques and groupware tools
2.6.11	Gabriela N. Aranda et al.	Springer Conference Article (2005)	Software Industry	Literature Review, Survey	Presented a cognitive approach to select elicitation techniques and groupware tools

Summary of Contributions

The studies presented in this section suggested some groupware/communication tools that can be used for the requirements elicitation process in global software development projects. Some of these articles also suggested design variations for these tools that can improve tool effectiveness for requirements elicitation process in distributed software development environments.

2.6.1 Somnoup Yos et al. (2018) presented a feature analysis study to recommend important features for groupware tools used during requirements elicitation process in global software development context. The authors generated a concise list of important features with four categories including workflow and change management, shared knowledge management, traceability, and system integration.

2.6.2 Carlos Solis et al. (2010) proposed a methodology to use spatial hypertext wikis as collaborative tool during requirements elicitation process in global software development projects. The authors proposed spatial hypertext wikis-based whiteboard mechanisms to share information and brainstorm ideas during requirements elicitation sessions in distributed software development projects.

2.6.3 Juan Manuel Carrillo et al. (2017) presented the specifications of a set of software features for groupware tools used during requirements elicitation process in global software development environments. The authors proposed an automated support mechanism for reuse-based requirements engineering process for global software development teams.

2.6.4 Gabriela N. Aranda et al. (2010) proposed a methodology to apply different strategies to recommend suitable groupware tools according to the cognitive characteristics of the software teams during requirements elicitation process in global software development projects. The authors also performed a case study, where they implemented one of these strategies in form of a software tool for distributed requirements elicitation process.

2.6.5 Gabriela N. Aranda et al. (2009) presented a methodology to select suitable groupware tools used during requirements elicitation process in global software development. The authors performed a controlled experiment to implement the methodology in form of a group tool that can be used in distributed software development environments.

2.6.6 Gabriela N. Aranda et al. (2009) presented a methodology to apply stakeholder's satisfactions to choose the most suitable groupware technologies in distributed requirements elicitation works. The authors presented the preliminary results of controlled experiment performed on software engineering students in a university to perform the groupware tools selection.

2.6.7 Gabriela N. Aranda et al. (2008) presented a set of strategies that can be used to select most suitable groupware tools in accordance with the characteristics of the involved virtual teams working in distributed software requirements engineering process. The authors used the cognitive profiles to select the most suitable groupware technology for different stakeholders of the requirements engineering process.

2.6.8 Gabriela N. Aranda et al. (2007) presented a methodology to choose groupware tools by considering stakeholders preferences during requirements elicitation process in global software development projects. The authors performed a controlled experiment to implement the methodology in form of a group tool that can be used in distributed software development environments.

2.6.9 Gabriela N. Aranda et al. (2006) proposed a method to select most suitable groupware technology for requirements elicitation process in distributed software development projects. The authors suggested the methodology to improve the groupware technology selection process for distributed requirements engineering task running in global software development projects.

2.6.10 Gabriela N. Aranda et al. (2005) presented a methodology to choose most suitable requirements elicitation techniques and groupware technologies using stakeholder's cognitive features for requirements elicitation process in global software development environments. The authors used the cognitive profiles to select the most suitable groupware technology for different stakeholders.

2.6.11 Gabriela N. Aranda et al. (2005) presented cognitive characteristics-based groupware tools and elicitation techniques selection methodology for requirements elicitation processes running in globally distributed software development projects. The authors used the cognitive profiles to select the most suitable groupware technology for different stakeholders of the requirements engineering process.

2.7 STUDIES ON PROCESSES AND METHODOLOGIES IN RE-GSD

This section includes those studies, which presented works on processes and methodologies proposed by researchers for requirements elicitation process for global software development environments. Only those research studies have been included in this section, which have been published in international journals and conferences of good repute since last two decades. Consider the table 2.4, which presents the complete empirical data of presented articles of this section.

Table 2.4 Studies on Processes and Methodologies in RE-GSD: Empirical Review

Article	Author	Publishing	Sample	Methods	Contributions
2.7.1	Naveed Ali et al.	John Wiley & Sons Journal Article (2016)	13 Undergraduate Students of SE/CS	Case Study Approach	Proposed a Method of Elicitation and Analysis for RE-GSD

2.7.2	Nosheen Sabahat et al.	IEEE Conference Article (2010)	None	Literature Review, Survey Method	Proposed an Iterative Approach for RE-GSD
2.7.3	Nuzhat Sultana et al.	Journal Article (2015)	Five Software Developers	Survey, Interview	Proposed an Iterative Technique for RE-GSD
2.7.4	Zafar Ul Islam et al.	Conference Article (2012)	None	Simple Literature Review	Proposed a Systematic Approach of RE-GSD
2.7.5	Gabriela N. Aranda et al.	IGI Global Journal Article (2009)	Post-Graduate Students of SE/CS	Questionnaire, Controlled Experiment	Proposed a Requirements Elicitation Methodology for GSD Teams
2.7.6	Gabriela N. Aranda et al.	Conference Article (2008)	Post-Graduate Students of SE/CS	Questionnaire, Controlled Experiment	Proposed a Methodology to Minimize Geographical Dispersion Issues
2.7.7	Gabriela N. Aranda et al.	IEEE Conference Article (2005)	Software Engineers	Experiment	Proposed an Approach to Improve Elicitation for GSD Projects
2.7.8	M. Ramzan et al.	Springer Conference Article (2011)	None	Case Study Approach	Proposed a Value-Based Elicitation Method for GSD Teams
2.7.9	Juan P. Mighetti et al.	CLEI Journal Article (2016)	Two Software Projects	Experiment	Proposed RE Process for GSD Teams
2.7.10	Hakim Bendjenna et al.	Springer Conference Article (2008)	Two Project Stakeholders	Case Study Approach	Proposed Elicitation Technique Selection for GSD Context

2.7.11	Hadi Ghanbari et al.	Elsevier Journal Article (2015)	Two Groups from Software Industry	Empirical Study, Experiment	Proposed an Approach for RE-GSD Using Online Games
2.7.12	Gabriela N. Aranda et al.	CLEI Journal Article (2008)	24 Post-Graduate Students of CS Program	Experiment	Proposed a Methodology for Challenges and Strategies in RE-GSD
2.7.13	Achim Menten et al.	IEEE Conference Article (2010)	Software Development Teams	Structured Interviews	Proposed a method to use audio and collaborative technologies for RE-GSD
2.7.14	Juan M. Carrillo de Gea et al.	Springer Journal Article (2016)	Students	Experiment	Proposed a re-used based approach for RE process in GSD

Summary of Contributions

The studies presented in this section proposed some preliminary level processes, methods, techniques and methodologies for global software development contexts to improve requirements elicitation process by improving communication mechanisms, collaborating technologies, information sharing strategies and work distribution guidelines. Some articles introduced requirements elicitation techniques for GSD projects while some of them highlighted reuse-based approaches.

2.7.1 Naveed Ali et al. (2016) proposed a requirements elicitation and analysis method for global software development teams. The proposed method is consisting of four stages of work including data collection stage, stakeholders educating stage, post-education assessment stage and requirements elicitation and analysis stage.

2.7.2 Nosheen Sabahat et al. (2010) presented a requirements elicitation approach for global software development environments. The authors performed a comprehensive literature review of existing RE approaches and highlighted the limitations of each of existing approach for GSD projects.

2.7.3 Nuzhat Sultana et al. (2015) proposed an iterative technique of requirements elicitation process for global software development projects. The authors also highlighted few problems of requirements elicitation in GSD and proposed some suggestions to overcome those problems.

2.7.4 Zafar Ul Islam et al. (2012) presented a systematic requirements elicitation approach for global software development projects. The authors highlighted major challenges of requirements elicitation in GSD environments and suggested different solutions and strategies to manage them. The authors provided different strategies to tackle the problems of misunderstanding during requirements elicitation process in GSD projects.

2.7.5 Gabriela N. Aranda et al. (2009) proposed a cognitive based requirements elicitation methodology for globally distributed software developments teams working in GSD projects. The authors suggested different mechanisms to improve the communications during requirements elicitation process in GSD projects. The authors provided different strategies to tackle the problems of misunderstanding during requirements elicitation process in GSD projects.

2.7.6 Gabriela N. Aranda et al. (2008) presented a methodology to reduce the geographical dispersion-based issues faced by software engineers during requirements elicitation process in global software development environments. The authors provided different strategies to tackle the problems of misunderstanding during requirements elicitation process in GSD projects.

2.7.7 Gabriela N. Aranda et al. (2005) presented a cognitive based requirements elicitation approach for global software development environments to improve the whole process. The authors introduced cognitive-based requirements elicitation tool and techniques selection process to improve the elicitation work. The authors also suggested the use of cognitive sciences to improve the requirements elicitation process for geographically distributed software development teams.

2.7.8 M. Ramzan et al. (2011) proposed an innovative value-based requirements elicitation approach using analytical hierarchy process for global software development projects. The authors introduced the concept of eliciting requirements from only valued stakeholders to improve the elicitation process for GSD environments. The authors also proposed an automated process of categorization and selection of only valued stakeholders for the requirements elicitation process in global software development projects.

2.7.9 Juan P. Mighetti et al. (2016) presented a requirement engineering process for globally distributed software development teams by considering the technique of lexical analysis in software development processes. The authors formulated the process by using a lexicon model and applied scenarios in order to mitigate the obvious threats to requirements engineering process in global software development environments.

2.7.10 Hakim Bendjenna et al. (2008) proposed an enhancement in the requirements elicitation techniques selection process for cooperated global software development environments. The authors presented a complete mathematical computational model for improved process of requirements elicitation technique selection for GSD projects.

2.7.11 Hadi Ghanbari et al. (2015) proposed online serious games-based requirements elicitation approach for globally distributed stakeholders of software projects. The authors highlighted that the results of the performed empirical study revealed that the proposed requirements elicitation approach easily enabled less-experienced software engineers to identify a higher number of product requirements.

2.7.12 Gabriela N. Aranda et al. (2008) introduced a requirement engineering methodology to determine the different issues faced by requirements engineering teams in global requirements development context. The authors highlighted that most of the challenges faced during the global requirements engineering process are related to lack of face-to-face communication and participants discomfort with the use of groupware technologies.

2.7.13 Achim Menten et al. (2010) proposed a methodology to use audio and collaborative technologies like wiki systems to perform requirements elicitation process and consequent documentations in globally distributed software development projects. The authors also guided about the corresponding software tool that can be developed to support their methodology of implementing wiki technologies in distributed requirements elicitation process.

2.7.14 Juan M. Carrillo de Gea et al. (2016) proposed a reuse-based approach for requirements engineering process in globally distributed software development projects. The authors specially emphasized on the use of specification techniques like parameterized requirements and traceability relationships for distributed requirements engineering activities to improve the quality of process. The authors claimed that the concept of requirements reusability during requirements elicitation process improves the elicitation works in globally distributed software development environments.

2.8 STUDIES ON MODELS AND FRAMEWORKS IN RE-GSD

This section includes those studies, which presented works on models and frameworks proposed by researchers for requirements elicitation process for global software development environments. Only those research studies have been included in this section, which have been published in international journals and conferences of good repute since last two decades. Consider the table 2.5, which presents the complete empirical data of presented articles of this section.

Table 2.5 Studies on Models and Frameworks in RE-GSD: Empirical Review

Article	Author	Publishing	Sample	Methods	Contributions
2.8.1	Huma Hayat Khan et al.	IEEE Conference Article (2014)	Software Industry	Industrial Survey Method	Proposed a Situational RE Framework for GSD Projects
2.8.2	Huma Hayat Khan et al.	Journal Article (2016)	None	Traditional Literature Review	Reported Formulation and Design of Situational RE Framework for GSD Projects

2.8.3	Muhammad Asgher Nadeem et al.	Journal Article (2019)	Two Pharmaceutical Companies	Case Study Approach	Proposed a RE Framework Using Case-Base Reasoning for GSD Work
2.8.4	Alsahli Abdulaziz Abdullah et al.	Journal Article (2015)	None	Systematic Literature Review (SLR)	Proposed FreGSD Framework for RE-GSD
2.8.5	Mahmood Niazi et al.	Conference Article (2012)	Five GSD Based Software Companies	Interviews	Proposed GlobReq Framework for RE-GSD Environments
2.8.6	Neetu Kumari et al.	IEEE Conference Article (2013)	Industry Experts	Survey, Interviews	Proposed Requirements Elicitation Framework for GSD Projects
2.8.7	Gabriela N. Aranda et al.	Springer Journal Article (2010)	24 SE Students & Teachers	Interviews, Questionnaire	Proposed a Framework to Improve Communication in RE-GSD
2.8.8	Muhammad Yaseen et al.	Journal Article (2018)	Five Software Companies	Systematic Literature Review	Proposed a RE Model "REM" for RE-GSD

Summary of Contributions

The studies presented in this section proposed different models and frameworks to improve requirements elicitation process in global software development contexts by improving communication mechanisms, collaboration mechanisms, information sharing strategies and work distribution guidelines. The presented studies mostly focused the traditional barriers of global software development like geographical distribution, temporal dispersion, cultural diversity and linguistic diversity to improve the requirements elicitation process.

2.8.1 Huma Hayat Khan et al. (2014) conducted a survey in the industry and performed statistical analysis to identify the most influential situational factors, which can affect requirements engineering activities in global software development context. The authors formulated a framework for situational requirements engineering for global software development by using these situational factors.

2.8.2 Huma Hayat Khan et al. (2016) presented a formulation and design of situational requirements engineering framework based on situational factors. The authors listed 22 situational factors sub-divided into 112 sub-factors and categorized in five major categories. The authors also debated the role of situational factors in improvement of whole process of requirements elicitation for globally distributed software development environments.

2.8.3 Muhammad Asgher Nadeem et al. (2019) presented a framework based on case base reasoning to improve communication during requirements elicitation process for global software development. The authors provided general guidelines about challenges of global software development faced by software developers and discussed certain parameters of the domain to resolve the issues of communications during requirements elicitation process in globally distributed software development teams.

2.8.4 Alsahli Abdulaziz Abdullah et al. (2015) proposed a framework "FreGSD" to support different activities of requirements engineering process in global software development environments. The authors claimed that the proposed framework would help the developers to minimize challenges of global software development.

2.8.5 Mahmood Niazi et al. (2012) proposed a framework "GlobReq" for requirements engineering process in global software development environments. The authors claimed that proposed framework would help the developers to manage the requirements engineering tasks in a better way for GSD based projects.

2.8.6 Neetu Kumari et al. (2013) highlighted the issues that degrade the requirements elicitation process in global software development projects and proposed a traditional framework to improve the elicitation process. The authors discussed different problematic issues of requirements elicitation process that may occur in global software development environments.

2.8.7 Gabriela N. Aranda et al. (2010) proposed a framework for global software development environments to improve the communication mechanisms during requirements elicitation process. The authors highlighted a set of problematic issues of GSD that may create difficulties during requirements elicitation process and proposed strategies to manage those issues.

2.8.8 Muhammad Yaseen et al. (2018) proposed a requirements elicitation model "REM" for global software development projects. The authors claimed that framework would address the factors, which positively and negatively affect the requirements elicitation process in GSD context.

2.9 CRITICAL ANALYSIS OF PRESENTED STUDIES

The critical analysis of all presented studies shows that, so far researchers addressed the following aspects of requirements elicitation process for global software development projects:

2.9.1 Identified Research Gaps

There were five different research gaps identified during the literature review of the domain for proposed framework background understanding. These research five gaps were identifying different research opportunities available for researchers. These five research gaps were combined together to formulate the research gap available to devise the proposed framework.

Studies in Table-2.1 (Research Gap-1):

None of the studies presented in this section talked about the role of human perspective and contribution of user personality traits in requirements elicitation process for GSD projects. None of these studies discussed the challenges of requirements elicitation process generated by inappropriate role of human personality in the whole process. Hence, there was an opportunity for researchers to investigate the contributions of personality traits in requirements elicitation process for global software development projects.

Studies in Table-2.2 (Research Gap-2):

None of the studies presented in this section integrated these situational or environmental factors into any kind of process, method, model or framework to evaluate their overall impact on other factors of global software development context and requirements elicitation process. The majority of these studies are based on simple literature review method to collect the information about the highlighted situational factors without performing any industrial level validation tests. Hence, there was an opportunity for researchers to investigate such kind of models or frameworks, which should incorporate these situational factors to see their impact on requirements elicitation process for global software development projects.

Studies in Table-2.3 (Research Gap-3):

None of these studies talked about the integration of groupware tools in whole process of requirements elicitation for global software development projects. In addition, none of these studies suggested any design opportunity for user personality assessment mechanisms integrated in the groupware technology used during the interactive sessions of requirements elicitation process in GSD projects. Hence, there was an opportunity for researchers to devise groupware technology selection process integrated with the user's personality assessment process to better facilitate the users.

Studies in Table-2.4 (Research Gap-4):

None of these studies proposed any process, technique or methodology integrated with participant's (users) personality traits assessment procedures to improve the work for requirements elicitation process in global software development contexts. Hence, there was an opportunity for researchers to investigate such kind of processes, techniques, methods or methodologies that can incorporate user personality traits to customize their internal procedures to facilitate the users during requirements elicitation process in global software development contexts.

Studies in Table-2.5 (Research Gap-5):

None of these studies presented any kind of model or framework incorporated with user personality traits assessment procedures for requirements elicitation process in global software development contexts. None of these studies focused the human aspects like personality traits to customize the internal requirements elicitation tasks to facilitate the users in elicitation sessions for improving the overall quality of requirements gathering process. Hence, there was an opportunity for researchers to investigate a requirements elicitation framework incorporated/integrated with user personality traits assessment procedures to customize the internal tasks of elicitation process.

2.9.2 Final Recommendations:

The provided critical analysis of all research studies clearly highlight the deficiency of a user-centric requirements elicitation framework that should be based on user's personality traits for its internal tasks-customizations for globally distributed software development teams. This type of the user-centric requirements elicitation framework is expected to improve the elicitation process for global software development projects by considering the user's personality traits to create more facilitating environment for them.

2.10 CHAPTER SUMMARY

This chapter presented a comprehensive literature review of studies conducted about different aspects of requirements engineering process for global software development contexts. The chapter included 60 (sixty) research studies on requirements elicitation works published in international journals and conferences of good repute during last two decades (year-2000 to year-2020). The presented research studies have been categorized into five major categories including works on challenges and strategies in RE-GSD, works on situational factors in RE-GSD, works on groupware tools in RE-GSD, works on processes and methodologies in RE-GSD and works on models and frameworks in RE-GSD. The chapter presented a detailed critical analysis of all presented studies performed to identify the possible research opportunities/gaps. The chapter highlighted five major research opportunities/gaps found from the comprehensive literature review on requirements elicitation process in global software development contexts. The five highlighted research gaps have been merged together to formulate the need for the user-centric requirements elicitation framework for global software development teams. ***Studies in Section-2.4***, highlighted different problems or issues or challenges or barriers faced by software engineers while performing requirements elicitation work in global software development projects. The majority of these studies also talked about the possible solutions/strategies to manage or improve these challenges. The majority of the challenges highlighted emerge from the main hurdles of geographical distribution, temporal dispersion, cultural diversity, communication issues, knowledge management issues, control and coordination related issues and inappropriate communication and collaboration technologies-based issues. ***Studies in Section-2.5,*** highlighted different environmental, situational, or contextual factors affecting the requirements elicitation process in global software development environments. The authors commonly used simple literature review or systematic literature review methodology to collect information about such type of factors from already published literature and used traditional questionnaire-based survey methodology to validate these factors from researchers working in academia and/or industry. ***Studies in Section-2.6,*** suggested some groupware/communication tools that can be used for the requirements elicitation process in global software development projects. Some of these articles also suggested design variations for these tools that can improve tool effectiveness for requirements elicitation process in distributed software development environments. ***Studies in Section-2.7,*** proposed some preliminary level processes, methods, techniques and methodologies for global software development contexts to improve requirements elicitation process by improving communication mechanisms, collaborating technologies, information sharing strategies and work distribution guidelines. Some articles introduced requirements elicitation techniques for GSD projects while some of them highlighted reuse-based approaches. ***Studies in Section-2.8,*** proposed different models and frameworks to improve requirements elicitation process in global software development contexts by improving communication mechanisms, collaboration mechanisms, information sharing strategies and work distribution guidelines. The presented studies mostly focused the traditional barriers of global software development like geographical distribution, temporal dispersion, cultural diversity and linguistic diversity to improve the requirements elicitation process.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The research methodology generally refers to the strategical plan devised by the researchers to meet their research objectives or reach specific research goals (Salihu, 2016). The conduct of any research/investigation should follow a systematic process to reveal the expected facts or knowledge aspects in a repeatable rigorous way (Mohajan, 2018). The findings pursued by researchers using hit-and-trial methods are generally not considered as trustworthy research findings because these might not be generalizable for whole domain (Smith, 2017). The appropriate research methodology pledges maturity of the proceeded research work and its consequential findings to contribute in the whole body-of-knowledge of domain (Huarng, Rey-Martí, & Miquel-Romero, 2018). The validity of any conducted research endeavor is generally ratified in terms of procedures followed by the investigator for data collection and data analysis tasks as well as deployed research instruments (An, Kaploun, Erdodi, & Abeare, 2016). The researcher's analytical capabilities are considered as the prime instrument for any research endeavor, which is operationalized by the adoption of right research methodologies and research instrumentations (Bilgin, 2017).

The objective of this research was to develop a user-centric requirements elicitation framework for requirements engineering teams. The user-centricness in the proposed framework was accomplished by incorporating big-five personality traits of users to customize each step of elicitation process to facilitate users. The proposed framework was contextualized for geographically distributed software development teams working on offshore software projects. The framework was developed using a top-down hierarchical design, which systematically refines the top-level abstract constructs into low-level concrete design elements. Such type of hierarchical system development supportively enables the researchers to grasp underlying difficulties and complexities of the forecasted system. The use of such type of designs also enables the researchers to assimilate the different system components extracted at different levels of design hierarchy to produce the complete system.

This chapter comprehensively describes the research methodology followed during the development of the proposed framework and its evaluation in small-scale prototypic environment (pilot study) as well as in full-scale industrial environment (real study). The chapter includes the thorough details of research methods used during this research endeavor with instrumentations involved in the validation of the research. Accordingly, this chapter highlights different stages of research design along with different activities that have been carried out in each phase of development. The contents of this chapter include the research design, the chosen population characteristics, the sampling characteristics, the instrumentation used, the contents validity, pilot study design, data collection and analysis procedures. The complete details of each of these items is discussed in the subsequent sections of this chapter to understand the adopted research methodology.

3.2 RESEARCH DESIGN

The quality of any instigated research is significantly dependent on type of research tasks performed during the investigation and overall organization of these tasks as complete research design (Almalki, 2016). A research design is a complete research plan, which comprehensively represents the flow of all activities that have been taken to grasp the subsequent research findings (Brooks & Normore, 2015). The research design is planned as a systematic convergent process that focuses the work from research topic selection to final research findings justifying the hypothesis (Abutabenjeh & Jaradat, 2018). This research study was meticulously carried-out using experiment-based research approach in which proposed framework was significantly tested by applying it on randomly selected software development projects running in true global software development context. Therefore, the overall research design for the evaluation and testing of the proposed framework was divided into two main phases including a prototypic pilot study design and real-time industrial design.

3.2.1 Research Phases

The complete research experiment was divided into two major phases. In the first-phase, a small-scale pilot study was performed using controlled academic environment to test the validity of data collection methods, data analysis methods and research instrumentations used. In the second-phase, a full-scale real study was performed in real-time industrial environment to test the validity of proposed framework design and research hypothesis. The results obtained with use of proposed framework were compared with those of results obtained without use of proposed framework to observe the claimed improvements in requirements elicitation process. The primary data was collected using different data collection forms developed in accordance with IEEE recommended practice for software requirements specifications standard IEEE Std. 830 (IEEE Standards Association, 2009). The collected data was evaluated by domain experts in accordance with specified quality attributes of IEEE recommended practice for software requirements specifications used for documenting functional requirements, non-functional requirements and graphical user interface requirements (IEEE Standards Association, 2009). These IEEE defined quality attributes for a good SRS were used to judge/evaluate the quality of the generated software requirements as an outcome of the requirements elicitation process. The resulted outcome of the proposed framework was graded by assigning numerical weighted values to different qualitative attributes for their transformation from qualitative to quantitative form for future analysis.

3.2.2 Research Stages

The complete research design is systematically explained in figure-3.1 as flowchart comprising of different research stages involved in the development and evaluation of the proposed framework. The overall research activity was planned to cater through distinct measurable phases based on distinguishable major activities defining different milestones and deliverables of the whole process. Each stage of this research design is shortly explained in the following paragraphs:

First-Stage of research was primarily concerned with the domain-of-interest selection and understanding by doing traditional literature review in a horizontal way. At this stage, different research directions were explored on which future research was needed or recommended by different researchers of this domain. The most recently published research articles from different research journals and conferences of good repute were considered for this preliminary literature review. Hence, the focus of this stage was breadth-based literature review to understand the research highlighted by different researcher in the selected domain.

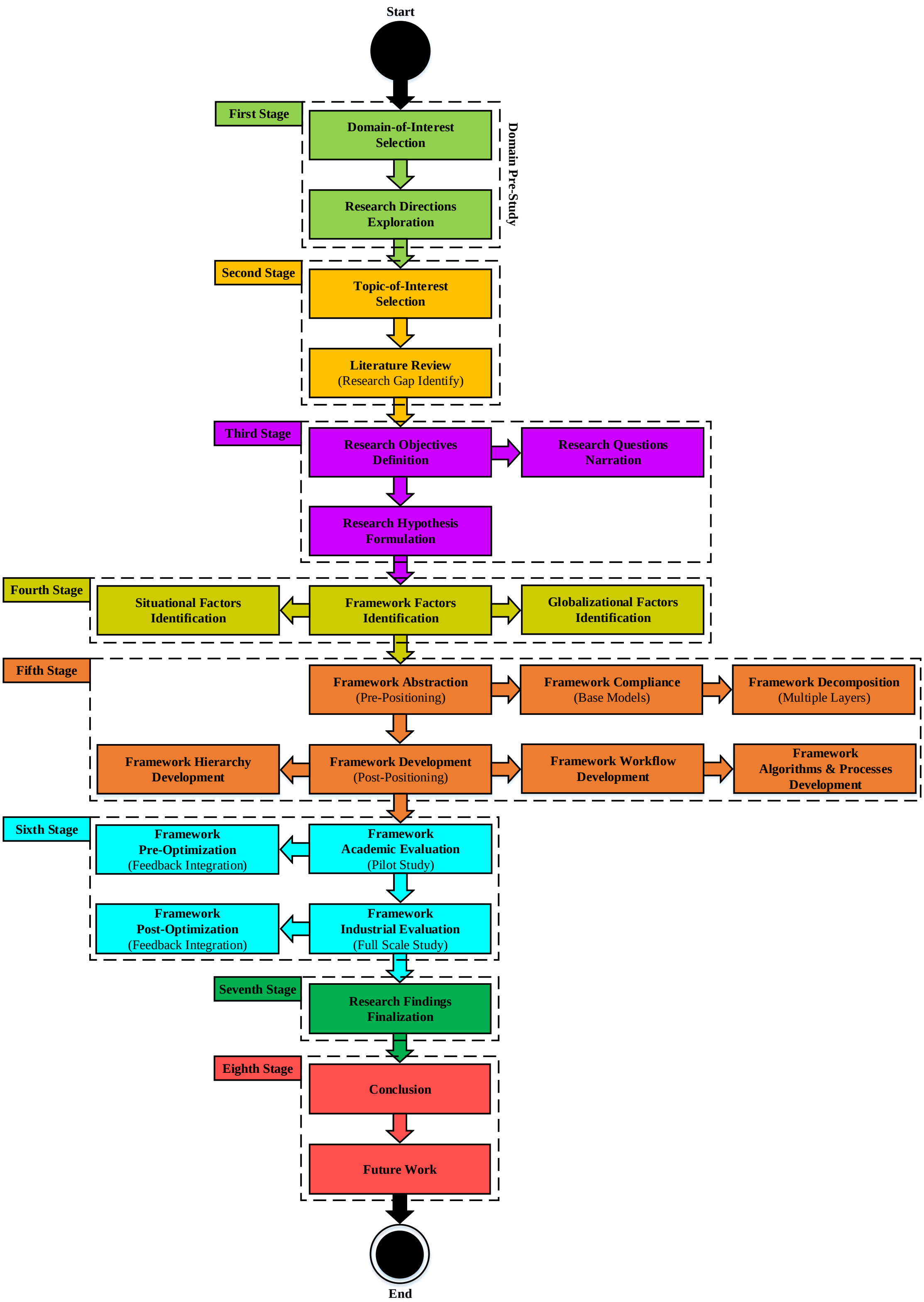


Figure 3.1 Complete Research Design

Second-Stage of research was concerned with topic of interest selection and research gap identification by doing traditional literature review in a vertical manner. At this stage, different research gaps were explored which were directly related to the topic-of-interest that was selected for future research work. The most recently published research articles from different research journals of good repute (with good indexing) were considered for this review to better authenticate the selected topic. The majority of the articles selected for this review were from very good repute journals of Springers and Elsevier. Hence, the focus of this stage was depth-based literature review to understand the state of art research so far established on the selected topic-of-interest.

Third-Stage of research was concerned with setting-up research objectives, defining/narrating research questions and formulating research hypothesis. At this stage, initially an abstraction level main research question was defined which concisely described the proposed framework essence and its applicability in the related domain. Afterwards, multiple research objectives were defined to construct multiple sub-questions at more concrete level to narrow the scope of main research question. Later on, the research hypothesis was formulated to support the anticipated research agenda covered by research objectives/questions in a well-structured manner.

Fourth-Stage of research was primarily concerned with the identification of different driving factors, which directly or indirectly influence the proposed framework. At this stage, a rigorous investigation was made by analyzing the most recently published research articles in well-known conferences, journals and other forms of literature. Two main types of driving factors were explored during this stage including globalization-factors (concerning with global software development context) and situational-factors (concerning with environmental context) which directly or indirectly affect the proposed framework. The influence of these driving factors was carefully analyzed to incorporate them in the development and evaluation process of proposed framework.

Fifth-Stage of research was concerned with the development of proposed framework using two sub-stages of design-iterations including framework pre-positioning stage and framework post-positioning stage. In framework pre-positioning stage, an abstract view of the proposed framework was developed in accordance with the existing body of knowledge and practices of the related domain. In this stage, framework external compliance with existing base models (foundation models) of requirements elicitation and global software development context was insured. In addition, framework internal decomposition in form of multiple layers/levels was crafted to decompose the complex structure into more manageable concrete working layers. In framework post-positioning stage, framework detailed design was crafted in two distinct sub-stages of design-iterations including framework hierarchy development and framework workflows development. At the end, the required algorithms (for technique and tool selection) and processes (for stakeholder's analysis and team selection) involved in framework workflows were developed to complete its computational part of hierarchy.

Sixth-Stage of research was concerned with the analysis and evaluation of proposed framework using academic setups (small-scale pilot study) as well as industrial setups (full-scale real study). In first phase of evaluation, a group of hundred students of undergraduate program from degree of software engineering was selected for performing academic evaluation of proposed framework in a controlled environment. After the completion of academic evaluation/testing, the pre-optimization of the proposed framework was performed to incorporate/integrate the observed deficiencies in devised techniques, tools and processes of proposed framework. In second phase of evaluation, three software development companies (having small, medium and large team distributions) working in global software development context were selected to perform the industrial evaluation of the proposed framework. After the completion of the industrial setups evaluation/testing, the post-optimization of the proposed framework was performed to incorporate/integrate the observed deficiencies in devised techniques, tools and process of proposed framework.

Seventh-Stage of the research was concerned with the generalization of established research results to align the research findings with domain body-of-knowledge and practices. At this stage, the formulated research hypothesis was also verified by analyzing the research findings and comparing them with the devised research hypothesis of the proposed framework. The well-defined structure of the proposed framework and its firm evaluation using controlled environment and industrial setups enabled the research to generalize the research findings.

Eighth-Stage of the research was concerned with concluding the research findings and defining the future work for the proposed framework. At this stage, the theoretical as well as practical implications of the proposed framework were considered to plan the future research directions in this domain. The future work is concerned with the optimization of framework to incorporate the traditional requirements elicitation.

3.3 THE POPULATION

The population generally refers to the entities of interests for planned research study and may comprised of different elements in quantitative form including peoples, organizations, systems, objects, things etc. (Nassaji, 2015). The population of any research study is its main representative for rationalization of hypothesis and anticipated research enquiry (Salman, Misirli, & Juristo, 2015). The population for any selected research should be characteristically homogenous enough to generalize the research findings produced from the selected sample of such population. In case of non-homogeneity in population, the selected sample may not show the true representation of the whole population due to which, the research findings might not be generalizable for the representation of whole population (Certo, Busenbark, Woo, & Semadeni, 2016).

In full-scale industrial evaluation, the representative population for real-time trial of the proposed framework was comprised of different software development companies working in global software development context for the development of offshore projects. Three different software development companies were selected nearby locality of the principal investigator of this research. The selected companies were developing different types of software for offshore clients through distributed software development teams (virtual teams) located in different countries of the world. The first selected company was based on low geographical distribution in its requirements engineering team. The second selected company was based on medium geographical distribution in its requirements engineering team. The third selected company was based on high geographical distribution in its requirements engineering team. The nature of projects run by these software development companies varies from android games development to android apps development on one hand while web service development on the other hand. The companies were randomly selected by just considering their context of projects, team distributions and physical locality with respect to principal researcher.

3.4 THE SAMPLE

A small set from the concerned study population known as sample is selected for the application and evaluation of the planned research. This sample set is systematically selected from sample frame of the population by applying sampling strategies and sampling methods (Taherdoost, 2016). This sample is selected in such a way that its results can be generalized for the whole population of study. There are different sample selection strategies and sampling methods used in scientific research. The quality and legitimacy of any research study is primarily dependent on the sample selection strategy and sampling methods used during research endeavor (Sarstedt, Bengart, Shaltoni, & Lehmann, 2017).

The probability sampling strategy was used to select the samples from the available population for the small-scale academic evaluation (pilot study) as well as full-scale industrial evaluation (real study) of the proposed framework. The probability sampling strategy was chosen because it gives the most reliable representative sample for selected populations (Speak, Escobedo, Russo, & Zerbe, 2018). The sampling methods used in probability sampling strategy facilitate the representative cross-sections and allow the selection of particular targeted groups from the available population (Speak, Escobedo, Russo, & Zerbe, 2018). In this study, the clustering sampling method was used to select the samples from available population. In pilot study, the clustering method was applied to select only those students for study who had successfully passed software requirements engineering course. In industrial study, clustering method was applied to select only those software development companies, which were located in nearby locality of researcher, and their projects were purely offshore projects managed by globally distributed software development teams. The selection of such nearby located software development companies enabled the researcher to easily reach company resources and collaborate with their team members at native country.

Accordingly, only three software development companies working in GSD context for the development of offshore projects were selected for the evaluation of the proposed framework. The choice of software development companies was based on the requirements engineering team distribution patterns and the kind of projects developed by these companies. The nature of projects run by these software development companies varies from android games development to android apps development on one hand while web service development on the other hand. The companies were randomly selected by just considering their context of projects, team distributions and physical locality with respect to principal researcher. First software-company was selected with low geographical distribution in its requirements engineering team. Second software-company was selected with medium geographical distribution in its requirements engineering team. Third software-company was selected with high geographical distribution in its requirements engineering team.

3.5 INSTRUMENTATION

The research instrument refers to the tools used for data collection and data analysis procedures during the conduct of anticipated research study (Mohajan, 2017). The both, internal validity and external validity conducted research greatly depends upon the perfection and quality of the research instruments used during data collection and analysis stages (Li, et al., 2015). The research instruments should be designed in such a way that data collection procedure and data analysis procedures should be facilitated by their use. This research study was an experimental research endeavor that was directly tested on the running projects of different software development companies working in true global software development context. The selected software development companies were comprised of geographically distributed software development teams scoped up to develop offshore software projects of like android games development, android apps development and web services development.

Accordingly, the analysis and evaluation of the proposed framework was initially performed in a controlled academic environment as a pilot study on a group of 100 students belonging to the undergraduate degree of software engineering in department of software engineering in a university. The pilot study was planned on the true GSD pattern in a prototypic environment and the data collection and data analysis strategies were replicated with those planned for real study. A set of twelve different forms were developed and applied on the experimented projects as research instruments during the data collection and analysis processes. Six forms were used for data collection purpose while the remaining six forms were used for data analysis purpose during the experimentation performed for evaluation of proposed framework. Details of these research instruments are given below:

3.5.1 Data Collection Forms

The data collection forms were used to collect different types of information related to participants of the study, project characteristics and product requirements. A set of six forms that were used for data collection during the data collection process are shortly explained below. Each data collection form was assigned a unique identifier abbreviated as *DCF (Data Collection Form)* to distinguish it from other forms used during data collection and analysis processes. The detailed contents of these data collection forms along with their usage have been discussed in chapter-5.

3.5.1.1 Personality Questionnaire Form

Personality Questionnaire Form (PQF) was based on big-five model-based personality assessment test that was derived through IPIP-50-Items personality assessment questionnaire (Akhtar & Azwar, 2019). This questionnaire is considered as the most authentic questionnaire used for the personality assessment of humans using big-five personality traits model (Akhtar & Azwar, 2019). The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.1.2 Personal Information Form

Personal Information Form (PIF) was developed to collect the personal information of participants during the evaluation process of proposed framework. The collected personal information using this form included full name, nickname, gender, age, qualification, contact number, email address, native country, native language, regional language, English language proficiency and cross-cultural experience. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.1.3 Work Information Form

Work Information Form (WIF) was developed to collect the working information of the participants at their organizations. This form was intended to collect information about working routines and office matters of participants along with their working preferences. The collected information using this form included designation, main job description, organization, office place, time-zone, availability schedule, RE role, Work experience, IT experience, RE experience, GSD experience, time preference, RE technique preference and RE tool preference. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.1.4 Project Information Form

Project Information Form (PIF) was developed to collect the information about the project characteristics along with project context to see the situation of project in terms of its available resources and status records. The project context was including the data about situational factors and globalization factors. The collected information using this form included project title, project type, project budgets, project schedules, project status, project resources, project deliverables, project milestones, project risks, organizational factors, stakeholders factors, project factors, process factors, product factors, temporal diversity, cultural diversity, linguistic diversity, team trust level, coordination and control and knowledge management. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.1.5 Stakeholders Information Form

Stakeholders Information Form (SIF) was developed to collect the information about the stakeholders of the project to completely plan the requirements elicitation sessions.

The stakeholders were broadly categorized into two main groups including primary stakeholders (as most important roles) and secondary stakeholders (as more and less important role). The secondary stakeholders were further divided into two sub-groups including secondary stakeholders with more important role and secondary stakeholders with less important role. The form was also used to collect the information about the mutual conflicts of these all stakeholders in terms of their preferences about work style, RE technique selection and RE tool selection during elicitation process. The collected information using this form included RE primary stakeholders list, RE secondary stakeholders list, RE primary stakeholder's mutual conflicts, RE secondary stakeholder's mutual conflicts and RE primary and secondary stakeholders across conflicts. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.1.6 Requirements Collection Form

Requirements Collection Form (RCF) was developed to collect the elicited requirements from the requirements elicitation teams after the successful completion of elicitation process. This form was developed in accordance with the guidelines provided by IEEE about the preparations of software requirements specifications document and standardized in IEEE standard Std. 830 (IEEE Standards Association, 2009). The collected information by using this form included project title, team number, team email address, team WhatsApp group name, analyst team members details and user team members details in first section of form. The remaining all sections of this form were purely based on IEEE software requirements specifications standard in form of five chapters including chapter-1 as introduction, chapter-2 as overall product descriptions, chapter-3 as system features, chapter-4 as external interface requirements and chapter-

5 as non-functional requirements. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.2 Data Analysis Forms

The data analysis forms were used to analyze different types of information collected from participants of the study related to project characteristics and product requirements. A set of six forms used for data analysis during the data analysis process are shortly explained below. Each data analysis form was assigned a unique identifier abbreviated as *DAF (Data Analysis Form)* to distinguish it from other forms used during data collection and analysis processes. The detailed contents of these data analysis forms along with their usage have been discussed in chapter-5.

3.5.2.1 Personality Assessment Form

Personality Assessment Form (PAF) was developed to analyze the data collected from the deployment of *Personality Questionnaire Form (PQF)* during data collection process. The personality assessment form was used to assess the personality traits of the respondents and generate the associated big-five personality patterns formulated as combinations of five traits of big-five model. The traits of big-five model include Openness, Conscientiousness, Extroversion, Agreeableness and Neuroticism (shortly known as OCEAN). There were thirty-two different OCEAN patterns that could be generated from personality questionnaire data ranging from OCEAN-00 (LLLLL or 00000) to OCEAN-31 (HHHHH or 11111). In this form, the data analysis was performed by using standard IPIP-50-items inventory evaluation formulas (19). The quantitative data set was derived for openness, conscientiousness, extroversion, agreeableness and neuroticism traits of participant. Then the scaling method was used to classify each trait value in low or high level to generate the desired OCEAN pattern. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.2.2 Team Characteristics Form

Team Characteristics Form (TCF) was developed to analyze the data collected from different data collection forms for project team's characteristics. The data about information of teams was collected partially in different forms and afterward combined together into this form to see the overall characteristics of the teams. The team characteristics helped the evaluator to plan the team's training more effectively, plan the effective elicitation sessions, choose the right elicitation technique and elicitation/groupware tool etc. The information analyzed through this form included team's geographical characteristics, situational characteristics, project-oriented characteristics and participant's characteristics etc. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.2.3 Training Evaluation Form for RE

Training Evaluation Form (TEF) for RE was developed to evaluate the effectiveness of requirements elicitation training given to participants at the early stage of evaluation process. The contents of evaluation form can vary from evaluator to evaluator depending on objectives of evaluation process and their ways of evaluation. The evaluation contents used for requirements elicitation training during this study were based on a set of short questions, which give the top overview of the whole requirements elicitation process. The given questions were assigned equal weightage to distribute the effectiveness measurement on overall process of requirements elicitation. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.2.4 Training Evaluation Form for GSD

Training Evaluation Form (TEF) for GSD was developed to evaluate the effectiveness of global software development training given to participants at the early stage of evaluation process. The contents of evaluation form can vary from evaluator to evaluator depending on objectives of evaluation process and their ways of evaluation. The evaluation contents used for global software development training during this study were based on a set of short questions, which give the top overview of global software development strategy, goals, benefits and challenges. The given questions were assigned equal weightage to distribute the effectiveness measurement on overall strategy of global software development. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.2.5 Training Evaluation Form for SRS

Training Evaluation Form (TEF) for SRS was developed to evaluate the effectiveness of software requirements specifications (SRS) training given to participants at the early stage of evaluation process. The contents of evaluation form can vary from evaluator to evaluator depending on objectives of evaluation process and their ways of evaluation. The evaluation contents used for software requirements specifications training during this study were based on a set of short questions, which give the top overview of the whole IEEE practice to document the elicited requirements using Std. 830 (IEEE Standards Association, 2009). The given questions were assigned equal weightage to distribute the effectiveness measurement on overall process of software requirements specifications development using IEEE Std. 830. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.5.2.6 Requirements Evaluation Form for RE

Requirements Evaluation Form (REF) was developed to assess the overall quality of elicited requirements during the proposed process of requirements elicitation. The IEEE recommended quality attributes were used to assess the quality of each section of each chapter of the SRS. The IEEE recommended quality attributes included correctness, unambiguousness, completeness, consistency, ranking, verifiability, modification and traceability (IEEE Standards Association, 2009). A variable set of weights were assigned to each section of each chapter of SRS by considering its importance and association with elicitation process. The overall quality factor of developed SRS was calculated by accumulating the quantitative quality results from all chapters of the document. The detailed contents of this form have been discussed in chapter-5 along with its usage.

3.6 CONTENT VALIDITY

The validity of any research reflects the trustworthiness and meaningfulness of its generated results (Flannelly, Flannelly, & Jankowski, 2018). The quality of generated results from any research endeavor is critically dependent on the opted research methods used, overall research design, instruments used, data collection procedures and data analysis procedures (Flannelly, Flannelly, & Jankowski, 2018). The validity of any conducted research can be defined in terms of appropriate usage of all these parameters in close suitability of research objectives and formulated research hypothesis (Noble & Smith, 2015). The research validity can be defined in terms of four main aspects including internal validity, external validity, construct validity and conclusion validity (Noble & Smith, 2015). These four facets of research validity for the design and evaluation of the proposed framework are explained below:

3.6.1 Internal Validity

The internal validity of a research reflects the firmness and suitability of research structure formulated through different procedures and adopted research instrumentations (Norris, Plonsky, Ross, & Schoonen, 2015). The internal validity shows the extent to which the results of the conducted research can be trusted depending upon the rigorousness of applied methods and instrumentations (Norris, Plonsky, Ross, & Schoonen, 2015). The following preventive measurements were taken during the anticipated research to improve the internal validity of study:

1. **Randomization:** The selected participants were randomly assigned different tasks of requirements elicitation process. The main categorization of tasks was based on the team's distribution as analyst team or user team.

2. **Random Selection:** The participant's selection was based on pure probabilistic method in which participants of the study were randomly selected from the population. The samples were selected using clustering technique.

3. **Double Blindness:** The double-blindness was used during the whole experimentation of the proposed framework in pilot study as well as in real study. Accordingly, both the participants and evaluators of study were kept unaware of the fact that their personality traits contribution in requirements elicitation process is point of observation in awaited research.

4. **Instrumentation:** A set of twelve different data collection and analysis forms were developed to use during pilot study as well as during real study of the proposed

framework. The contents variations in the formulated data collection and analysis forms were prohibited to keep the consistency of the measurements of observed artifacts.

5. **Experimental Manipulations:** In order to avoid the experimental manipulations of independent variables (user personality traits), the impact of globalization factors, situational factors and elicitation team preferences (analyst preferences and user preferences) were kept consistent for all groups of study throughout the whole project.

6. **Study Protocol:** The data collection procedure was fully automated throughout the whole study (pilot study as well as real study) using *Google Classroom* web service to ensure the consistency of the information collection procedures used in study.

7. **Participants Biasness:** The conducted experiment was repeated multiple times by shuffling the involved participants to minimize the impact of participant's biasness. All participants were given equal time and environment to improve their work as much as possible.

8. **Singularity Effects:** Multiple elicitation teams were engaged in the experiment under a symmetrical working environment to avoid the singularity effects that occur due to the trial on a single team. In pilot study, there were ten different teams involved for the evaluation of the proposed framework. In real study, there were three different software companies involved for the evaluation of the proposed framework.

9. **Attrition:** The participants were not allowed to leave the projected research study before its natural end to prevent the effects caused by attrition. The similar precautionary measurements were taken during pilot study as well as during real study.

10. **Regression Effects:** The allocated project during the evaluation experiment of the proposed framework was three times changed to avoid the statistical regression effects. In each iteration, the new scope of project was assigned to all participants to negate the effect of their natural experience obtained during the study.

The following additional preventive measurements were taken to raise the internal validity of the planned research design.

1. **Rigorous Pilot Study:** A rigorous pilot study was conducted for pre-evaluation of the proposed framework and its post-evaluation tools and techniques.

2. **Big-Five Personality Assessment:** The personality assessment was performed using standard big-five model-based NEO-IPIP 50-Items inventory, which is considered as the most reliable personality assessment tool for big-five personality traits.

3. **IEEE Standard Std. 830 Compliance:** The outcome of the elicitation process was drafted using IEEE standard Std. 830 (standard for software requirements specifications). The evaluation of the outcomes of elicitation process was also carried out using IEEE software requirements specifications quality attributes. The

data collection form developed for collection of requirements was entirely based on this standard.

3.6.2 External Validity

The external validity of a research refers to the generalizability of accomplished results in different settings during the experimentations (Moser & Korstjens, 2017). The main essence of external validity is to justify the generalization of generated results to contribute in the body of knowledge of the domain. The following preventive measurements were taken during the anticipated research to improve the external validity of study:

1. **Inclusion and Exclusion Criteria:** An inclusion criterion was defined for the selection of the participants to maintain the external validity of the research findings. Only those participants were involved in the study who had substantial knowledge about the requirements elicitation process and global software development context.

2. **Replications:** The same study was replicated on multiple teams under the symmetrical circumstances to take benefit of averaging effect from the generated results. During the pilot study, ten different teams of same size and characteristics were involved to perform the same experiment. During the real study, three different software development companies were involved to take the benefit of averaging effect from the generated results. In addition, the experiment was repeated two times with all these teams using different project to reduce the negative effects of project scope and characteristics.

3. **Field Experimentation:** The real study was performed in three different software development companies to nullify the biasness/effects of controlled environment used in the experimentation during the pilot study.

4. **Situational Factoring:** The participants were assigned to study using random selection for equal amount of time, resources and project scope to minimize the situational factoring effects during the study.

5. **Selection Biasness:** The participants of the study were selected using the similar inclusion and exclusion criteria in all companies to reduce the effects of selection biasness.

3.7 PILOT STUDY DESIGN

The pilot study generally refers to the small-scale study performed on a small group of participants belonging to the actual population of study or different population in a somewhat controlled environment (Ismail, Kinchin, & Edwards, 2017). The pilot studies are normally performed before the start of the actual research experiment in order to understand and evaluate the suitability of the research instruments (data collection forms and data analysis forms), data collection procedures and data analysis procedures (Mcgrath & Brandon, 2018). The pilot study is performed using a controlled environment in which some parameters of study are controlled to see their impact on the expected dependent variables of the study under hypothesized work environment (Mcgrath & Brandon, 2018). In *Pilot Study (Small-Scale Academic Evaluation)*, the demonstrative population for evaluation of proposed framework was comprised of undergraduate students of *Bachelor of Science in Software Engineering (BSSE)* program in software engineering department of a charted university. The software engineering department of selected university had a total strength of more than one thousand students in its undergraduate programs of *BSSE (Bachelor of Science in Software Engineering)* and *BSCS (Bachelor of Science in Computer Sciences),* which run as a full-time study programs in morning shift. The majority of the undergraduate students belong to the nearby locality of the university while a small group of students belong to the remote areas of the country and stay in hostels located near the university campuses. The students of both programs go through the basic courses of computer sciences and software engineering along with course from social sciences. Hence, the students were capable of demonstrating the technical skills of software engineering domain along with personality building soft skills needed to interact and collaborate with members of society. Additionally, the students of software engineering program also go through the specialized courses of software engineering domain including software requirements engineering, software design and architecture, software quality assurance, software verification and validation, software project management etc. The mainstream of population selected for trial test of proposed framework was belonging to the software engineering program where all students were already gone through the course of software requirements engineering.

The probability sampling strategy was used to select the samples from the available population for the pilot study (controlled academic environment evaluation) of the proposed framework. The probability sampling strategy was chosen because it gives the most reliable representative samples for selected populations of the study. The sampling methods used in probability sampling strategy facilitate the representative cross-sections and allow the selection of particular targeted groups from the available population. In this research study, the *Clustering Sampling* method was used to select the samples from available population of undergraduate degree students. The *Inclusion and Exclusion Criteria* defined for the selection of sample was based on the prerequisite knowledge of requirements elicitation process learnt by students in course of software requirements engineering. Hence, the clustering sampling method was used to select only those students of the entire population who had already passed the course of software requirements engineering in nearby semester. The sixth semester and eighth semester students were falling in the group of students who had passed the software requirements engineering course in their fifth semester. Therefore, the sixth semester students become eligible for the trial of proposed framework because they had passed software requirements engineering course in just previous semester. Accordingly, a group of only 100 students (out of total 1000 population) was selected from whole department of software engineering who already had a substantial amount of knowledge of software requirements engineering domain and a deep understanding of requirements elicitation process. Each student of the selected sample was also involved in the projects relating to software requirements elicitation process and software requirements specifications documentation according to IEEE standard Std. 830 (IEEE Standards Association, 2009) for SRS development. Hence, each student was well aware of the IEEE practices of documenting functional requirements, non-functional requirements and graphical user interface requirements in accordance with IEEE standard Std. 830.

3.8 DATA COLLECTION PROCEDURES

The data collection procedures generally refer to the methods used for the collection of the data during the evaluation of the conducted research with formulated research instrument used (Fritz & Vandermause, 2017). The validity of the anticipated research work is greatly dependent on the quality and authenticity of the data collection procedures used during study evaluation (Loomis & Paterson, 2018). Accordingly, the data collection procedures presented in this section describe the data collection process with the instrumentations used during the evaluation of the proposed framework. The data collection procedure was fully supported by online interactive sessions by using *Google Classroom* web service for each type of company. Three different google classes were created for three selected companies to perform online interactions to support global software development essence by allowing participants to perform interactions through online web service. The first google classroom class that was created had main title of *Real Study (UCRE Framework for GSD Teams)* and sub-title of *SC1 (Low Geographical Distribution).* Similarly, the second google classroom class that was created had main title of *Real Study (UCRE Framework for GSD Teams)* and sub-title of *SC2 (Medium Geographical Distribution).* Similarly, the third google classroom class that was created had main title of *Real Study (UCRE Framework for GSD Teams)* and sub-title of *SC3 (High Geographical Distribution).* The details of company structures are explained in chapter-5. A set of six data collection forms were developed to collect different types of participant's information using online google classroom facility. These developed forms were distributed to class participants as their class/project assignments in MS Word format and were asked to fill these forms and submit back in the prescribed time using google classroom assignment turn-in option. The data collection forms were distributed to participants in four iterations depending on the type of information collected from them. In first iteration, the Personality *Questionnaire Form (PQF)* was assigned to participants to submit back in the prescribed time. In second iteration, the *Personal Information Form (PIF)* and *Work Information Form (WIF)* were assigned to participants to submit back in the prescribed time. In third iteration, the *Project Information Form (PIF)* and *Stakeholders Information Form (SIF)* were assigned to participants to submit back in the prescribed time. In fourth iteration, the *Requirements Collection Form (RCF)* was assigned to participants to submit back in the prescribed time. The complete log and online record were maintained about all kinds of interactions performed with software development companies during industrial evaluation of proposed framework. Therefore, a complete log and online record of data collection activities via data collection forms has been maintained which can be monitored to see the details of data collection forms assignment and their submission.

3.9 DATA ANALYSIS PROCEDURES

The data analysis procedures generally refer to the processes followed for the analysis and evaluation of the collected data to perform the validity testing of the research (Taherdoost, 2016). The data analysis forms or sheets are used by evaluator to assess the accuracy and authenticity of the generated results from the conducted research (Heale & Twycross, 2015). Therefore, the design and implementation of data analysis procedures should be strongly aligned with already well-proven research in the selected domain of study (Lub, 2015). Accordingly, the data analysis procedures discussed in this section refer to the processes followed for the analysis and evaluation of the collected data during evaluation process of the proposed framework. The collected data during this research was in mixed form (qualitative as well as quantitative). Most of the data collected for the evaluation of the proposed framework was in qualitative form while few parts of collected data were in quantitative form. A set of six data analysis forms were developed to evaluate the collected data using appropriate data analysis procedures. In first iteration, the *Personality Assessment Form (PAF)* was used to assess the personality traits of the participants of the study and generate big-five personality patterns for onward processing. The personality assessment was performed by using a standard big-five personality test IPIP-50-Items inventory (Akhtar, H., 2019). In second iteration, the *Team Characteristics Form (TCF)* was used to find out the characteristics of the teams involved in the evaluation process. This analysis played a primary role to better plan the tasks of team's trainings, elicitation technique and tool selection and elicitation session conduct. In third iteration, the three *Training Evaluation Forms (TEF) for RE*, GSD and SRS were used to evaluate the participants knowledge about requirements elicitation process, global software development strategy and software requirements specifications documentation. In forth iteration, the *Requirements Evaluation Form (REF)* was used to evaluate the quality of the requirements received as qualitative data after the completion of the requirements elicitation process. The collected qualitative data was handed over to two independent evaluators for review and expert judgment. One evaluator was academician from domain of software engineering while the second evaluator was software engineer/developer from the software development industry.

3.10 CHAPTER SUMMARY

This chapter presented the details of complete research methodology followed during the development and evaluation of the proposed framework. The chapter highlighted eight different stages of anticipated research design along with different types of processes carried out in each stage. The chapter briefly discussed the characteristics of the population of study with corresponding sample chosen for the evaluation of the proposed framework during pilot study performed on undergraduate level students of software engineering program and real study performed on software development companies working in true global software development context. The chapter described the details of the data collection forms and data analysis forms used as instrumentations during the data collection procedures and data analysis procedures of the planned study. The chapter discussed the internal and external validity of conducted research by underlining validity of selected research methods, data collection procedures, data analysis procedures and research instrumentations used during experiment. The chapter presented the design of pilot study conducted for the pre-evaluation of the proposed framework using a controlled academic environment. The chapter presented the details of data collection procedures and data analysis procedures catered during the conduct of presented research study.

CHAPTER FOUR

PROPOSED FRAMEWORK

4.1 INTRODUCTION

Requirements Elicitation is considered as the foremost important activity performed during the requirements engineering stage of software development (Anwar & Razali, 2016). The requirements elicitation process is performed at early stages of requirements engineering and is full of cross-sectional conversations among participants using formal and informal communication mechanisms (Sutcliffe & Sawyer, 2013). The success of the requirements elicitation process is critically dependent on the analytical capabilities of its participants and their interpersonal skills (Shuhud, Richter, & Ahmad, 2013). The requirements elicitation is traditionally based on the iteratively executed elicitation sessions using different elicitation methods and elicitation tools. The requirements analyst team plans these elicitation sessions by considering the involved stakeholders, nature of requirements, sources of requirements and sources of project (Lane, O'Raghallaigh, & Sammon, 2016). The outcomes of requirements elicitation process are documented in form of software requirements specifications using standard templates provided by different standardizing organizations (Ali & Lai, 2016). The software development companies sometimes have developed their own standard templates for documenting stakeholder's requirements instead of following any external template.

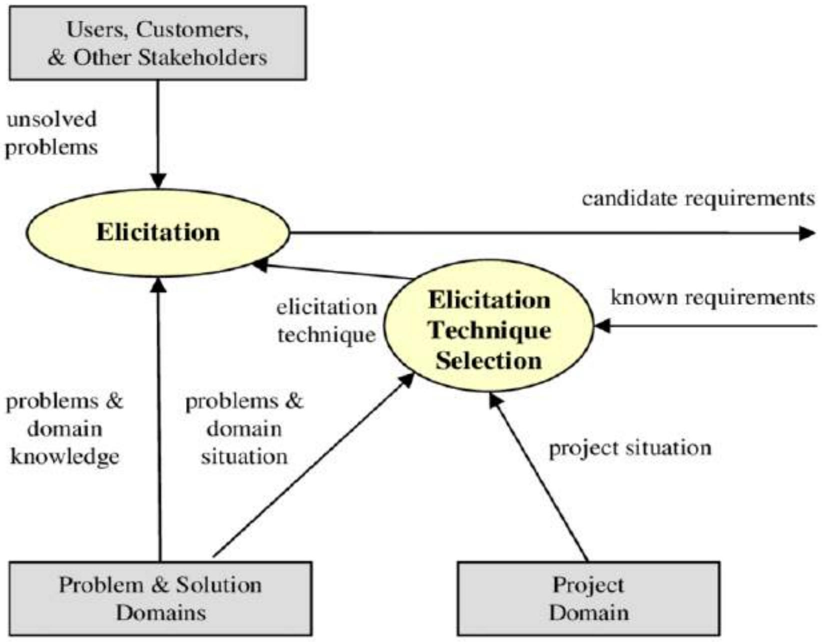
Requirements Elicitation Framework refers to the set of activities performed before requirements elicitation sessions, set of activities performed during requirements elicitation sessions and set of activities performed after the requirements elicitation sessions (Rana & Tamara, 2015). The requirements elicitation framework is a more elaborated form of requirements elicitation models, which only focus on the inputs and outputs of elicitation process along with different activities performed to transform elicitation inputs into elicitation outputs (Muqeem & Beg, 2014). The different activities performed before the start of requirements elicitation sessions are commonly known as pre-elicitation activities, which may include background understanding, organization understanding, project understanding, stakeholders understanding, requirements sources understanding, elicitation team composition, elicitation technique selection, elicitation technology/tool selection and elicitation session planning (Shuhud, Richter, & Ahmad, 2013). The different activities performed during the requirements elicitation sessions are commonly known as in-elicitation/elicitation activities, which may include elicitation session introduction, elicitation session main body design, elicitation session close-ups and elicitation session follow-ups (Shuhud, Richter, & Ahmad, 2013). The different activities performed after the requirements elicitation sessions are known as post-elicitation activities, which may include elicitation results documentations, elicitation results negotiations, elicitation results verification and validations, elicitation session repetition and elicitation results communication (Shuhud, Richter, & Ahmad, 2013).

4.2 BASE OF PROPOSED FRAMEWORK

The proposed framework is a requirements elicitation framework developed for global software development contexts. The framework considers situational requirements engineering factors during elicitation tools and techniques selection process. The design of proposed framework is based on philosophies introduced by three articles. The first article by Ann M. Hickey (Hickey & Davis, 2004) proposed a unified requirements elicitation model. The second article by Gabriela N. Aranda (Aranda, Vizcaíno, & Piattini, 2010) proposed a requirement gathering model for global software development projects. The third article by Huma Hayat Khan (Khan, Malik, Chofreh, & Goni, 2018) presented a set of situational requirements engineering factors for global software development. These three articles published in good repute international journals and conferences became the base articles for the cross-validation of the proposed framework. The proposed framework fully justifies the parametric aesthetics of these three articles and subsequently is in accordance with all those articles, which have been published on the philosophical conceptions of these articles. The details of these three base articles are presented in the following subsequent sections to explain their theories and design artifacts.

4.2.1 Unified Model of Requirements Elicitation

In article by Ann M. Hickey, the authors proposed a unified model for requirements elicitation, which emphasizes on the execution of requirements elicitation process as iterative elicitation sessions (Hickey & Davis, 2004). The proposed requirements elicitation model transforms the current state of product requirements and project situations into an improved state of requirements and situation of project. This requirements elicitation model served as the foundation for other requirements elicitation models, frameworks and methodologies that have been proposed since last two decades. Consider the given figure-4.1 (Hickey & Davis, 2004), which explains the overall concept of requirements elicitation model proposed by authors of this article. The inputs to this model include problem-domain and solution-domain characteristics, project-domain characteristics, known requirements and stakeholder’s unsolved problems. The model provides a mechanism of elicitation technique selection method, which selects an appropriate requirements elicitation technique for the requirements elicitation process. The output of the proposed model is in form of a set of candidate requirements that have been certified by requirements engineering teams.

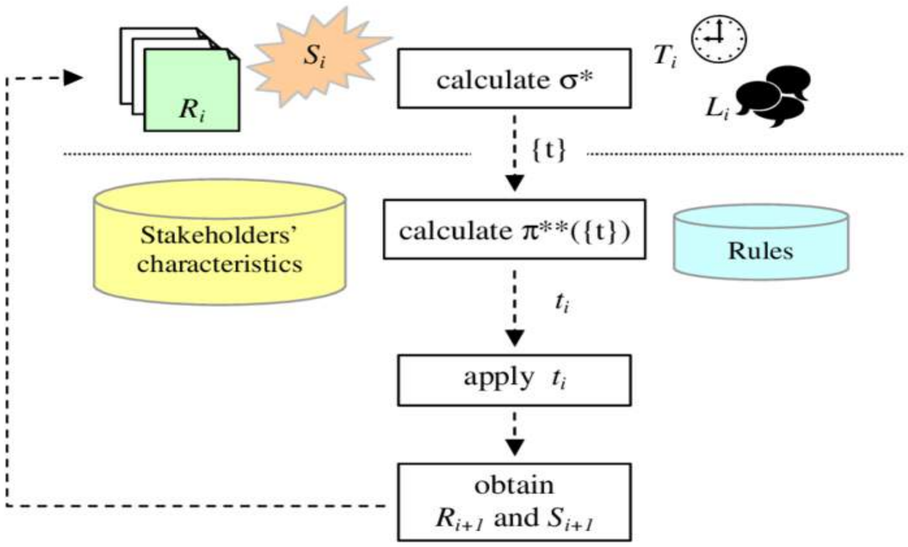


https://www.researchgate.net/figure/Details-of-elicitation-activities-Hickey-and-Davis-2002_fig1_221235268 (Hickey & Davis, 2004)

Figure-4.1 Unified Model of Requirements Elicitation

4.2.2 Requirements Gathering Model for GSD Projects

In an article by *Gabriela N. Aranda, the authors* proposed a framework to improve communication during requirements elicitation process in global software development projects (Aranda, Vizcaíno, & Piattini, 2010). In this framework, the authors formulated a requirement gathering model for global software development projects to support requirements elicitation technique and tool selection processes. In their framework, the authors introduced three main stages of preliminary data collection stage, virtual team definition and problem detection & solution stage and requirements gathering stage. Consider the given figure-4.2 (Aranda, Vizcaíno, & Piattini, 2010), which represents the requirements gathering model for global software development projects presented by authors in their framework. The presented requirements gathering model initially calculates parameters on the basis of requirements status Ri, project situation Si, temporal dispersion Ti and language diversity Li. The output of initial phase is a set of suitable requirements elicitation techniques "{t}" which becomes input for the next stage. The next stage uses parameters of preference rules and stakeholder's characteristics to purify the set {t} and find out most suitable requirements elicitation technique "t_i" for an elicitation session. At the end, the model applies this technique on selected elicitation session and gets an updated status of requirements R_{i+1} and project situation S_{i+1}

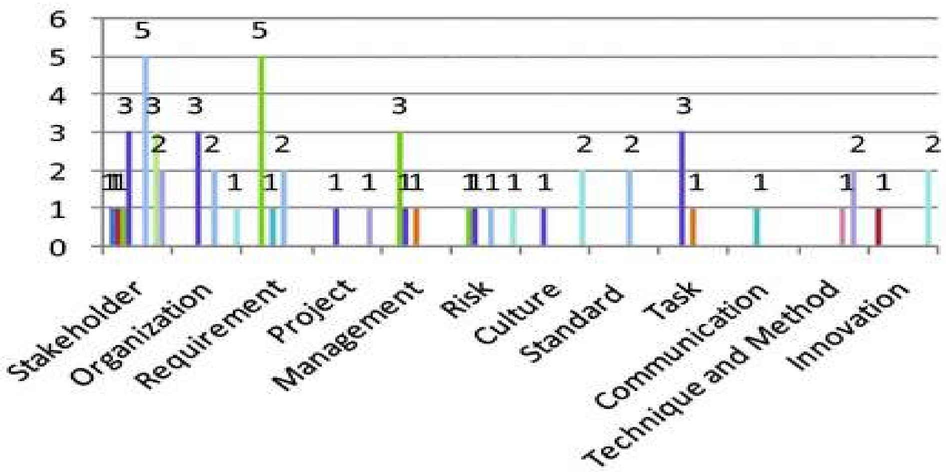


https://www.researchgate.net/figure/Requirement-elicitation-in-distributed-environments-as-an-iterative-process-of_fig2_221235268 (Aranda, Vizcaíno, & Piattini, 2010)

Figure-4.2 Requirements Gathering Model for GSD Projects

4.2.3 Situational Requirements Engineering Process

In an article by *Huma Hayat Khan, the authors* presented a study on situational requirements engineering in global software development contexts (Khan, Malik, Chofreh, & Goni, 2018). The authors highlighted twelve situational factors that may influence the whole process of requirements elicitation in global software development projects. The highlighted situational factors of requirements engineering include organization, stakeholders, requirements, management, project, culture, risks, standards, communication, tasks, innovation, techniques and methods. Consider the given figure-4.3 (Khan, Malik, Chofreh, & Goni, 2018), which shows these twelve situational factors of requirements engineering according to the frequencies found in the results of literature survey performed by authors. The authors debated that requirement elicitation process can be improved for global software development projects/contexts if these twelve situational factors are managed positively during requirements elicitation sessions.



https://link.springer.com/chapter/10.1007/978-3-319-59427-9_89
(Khan, Malik, Chofreh, & Goni, 2018)

Figure-4.3 Situational Requirements Engineering Factors

4.3 THEORY OF PROPOSED FRAMEWORK

The proposed framework is a requirements elicitation framework for global software development teams. The main contribution of the proposed framework is its user-centeredness capability incorporated to customize the different processes and algorithms during the whole process of requirements elicitation. The user-centeredness is incorporated in the proposed framework by using parameter of user personality traits using big-five personality assessment model. The user personality traits are assessed at early stages of proposed framework and used in subsequent processes and algorithms to select most suitable requirements elicitation teams, requirements elicitation techniques and requirements elicitation tools. Hence, the user personality traits are used to determine the most suitable requirements elicitation contexts by selecting most suitable elicitation teams, elicitation techniques and elicitation tools. The proposed framework is presented using four different views including framework abstract view, framework process view, framework structural hierarchical view and framework execution workflows view. The framework structural hierarchy shows the different levels/layers of processes running in the framework body. The framework execution workflows show the sequence and stages of different processes running inside the framework to support the requirements elicitation process. The proposed framework structure is based on a hierarchy consisting of six different levels including one abstract level and remaining five concrete levels. The abstract level of the hierarchy represents the requirements elicitation process as an abstract entity comprised of certain inputs and outputs streams. The remaining five levels of the proposed framework are concrete levels including level-1 (elicitation stages), level-2 (elicitation phases), level-3 (elicitation processes), level-4 (elicitation activities) and level-5 (elicitation tasks). The levl-5 of the proposed framework is comprised of elicitation tasks, which can be further extended into sub-tasks to represent the different work tasks. Consider the given figure-4.4, which shows all these abstraction levels/layers of the proposed framework to map the presented concept of layered hierarchical structure.

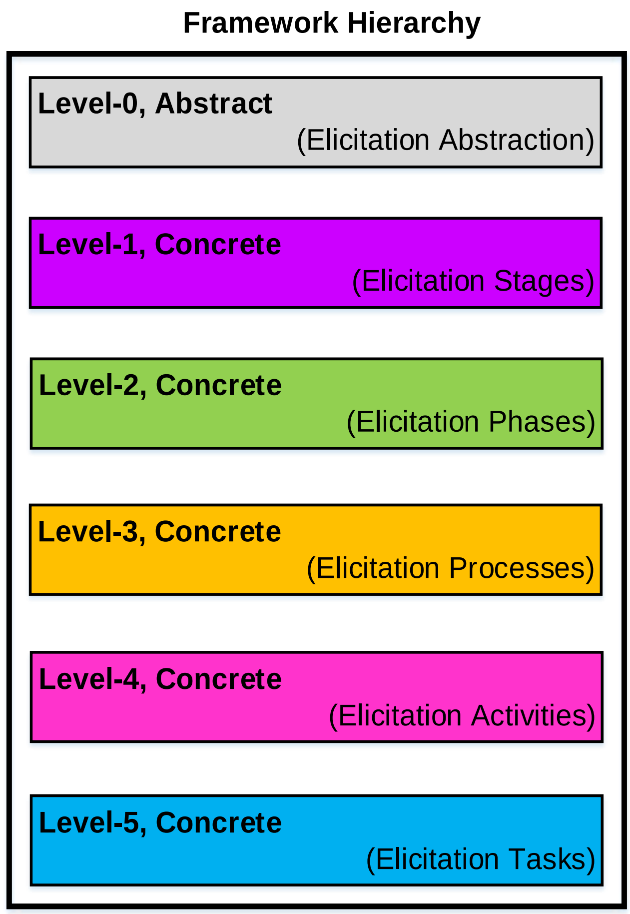


Figure-4.4 Abstraction Levels in Framework Structural Hierarchy

4.4 PROPOSED FRAMEWORK ABSTRACT VIEW

The abstract view of the proposed framework is comprised of two different abstraction levels including tope-abstract view and bottom-abstract view as is shown in the given figure-4.5. In the proposed framework, the top-abstract view is the abstract view of the main abstract view while the bottom-abstract view is the somewhat concrete view of the main abstract view. Therefore, going from top to bottom reduces the abstraction of design of proposed framework and therefore increases the refinement of the design of proposed framework.

Top-Abstract View shows the requirements elicitation process as an activity running between requirements engineering pre-phases and post-phases. The top-abstract view of proposed framework shows different activities performed during the pre-phases of the requirements engineering process like project charter signing and preparation of vision a scope document etc. These activities are sometimes known as early requirements engineering activities, which should be completed before the start of the late requirements engineering activities. The top-abstract view also shows different activities performed after the completion of the requirements elicitation process like requirements analysis, requirements specifications and requirements quality assurance.

Bottom-Abstract View shows the details of the inputs and outputs of the requirements elicitation process along with its internal stages. The left side of this bottom-abstract view shows that inputs of the requirements elicitation process may include problem domain knowledge, solution domain knowledge, stakeholder's unsolved problems, project characteristics and organization characteristics. This view is fully aligned with unified requirements elicitation model proposed by Ann M. Hickey whose external inputs are comprised of these inputs to start requirements elicitation works. The right side of bottom-abstract view shows that the completion of all requirements elicitation sessions generates agreed requirements commonly known as candidate requirements. The middle side of the bottom-abstract view shows three different stages of the requirements elicitation process including elicitation stage-1 (pre-elicitation processes), elicitation stage-2 (elicitation processes) and elicitation stage-3 (post-elicitation processes).

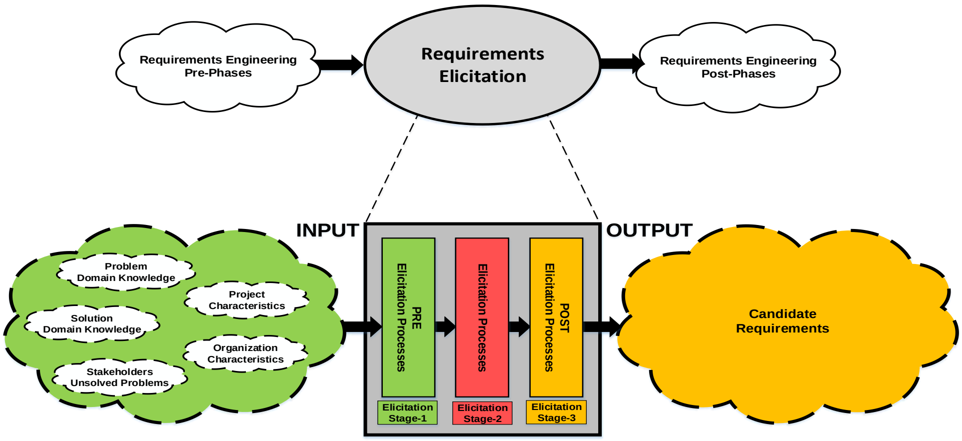


Figure-4.5 Proposed Framework Abstract View

4.5 PROPOSED FRAMEWORK PROCESS VIEW

The proposed framework process view is comprised of a set of twenty-four different processes that execute during the requirements elicitation. These processes are divided into three main categories including pre-elicitation processes, post-elicitation processes and elicitation processes. Consider the given figure-4.6, which shows these three categories of processes.

4.5.1 Pre-Elicitation Processes

The pre-elicitation processes of the proposed framework are those processes, which execute before the start of the requirements elicitation sessions and aimed to plan the elicitation sessions in accordance with the available situation. The pre-elicitation processes include background-understanding processes, organization understanding processes, project understanding processes, stakeholders/users understanding processes, data-sources understanding processes, requirements elicitation team planning processes, requirements elicitation approach planning processes, requirements elicitation technology planning processes and requirements elicitation session planning processes. The background-understanding processes include problem domain understanding process and solution domain understanding process. The organization understanding processes include organization knowledge/information understanding process. The project understanding processes include project contextual analysis process, project status/state understanding process, project resources familiarization process, project milestones understanding process and project deliverables understanding process. The stakeholder's/user's understanding processes include stakeholder's/user's evaluation process and stakeholder's/user's trainings process. The data-sources understanding processes include requirements sources identification process. The requirements elicitation team planning processes include elicitation team composition process. The requirements elicitation approach planning processes include elicitation technique selection process and elicitation technique customization process. The requirements elicitation technology planning processes include elicitation tool selection process. The requirements elicitation session planning processes include elicitation session preparation process.

4.5.2 Post-Elicitation Processes

The post-elicitation processes include elicitation repository processes, elicitation negotiation processes, elicitation confirmation processes, elicitation revision processes and elicitation results sharing processes. The elicitation repository processes include elicitation results documentation process. The elicitation negotiation processes include elicitation results negotiation process. The elicitation confirmation processes include elicitation results vetting process. The elicitation revision processes include elicitation process repetition process. The elicitation sharing processes include elicitation results communication process.

Figure-4.6 Proposed Framework Process View

4.5.3 Elicitation Processes

The elicitation processes include elicitation session introduction process, elicitation session main-body defining process, elicitation session close-up defining process and elicitation session follow-up defining process. The elicitation processes are mostly run as different elicitation management activities required to accomplish the requirements elicitation sessions successfully according to the planned strategy. The elicitation processes are always executed in accordance with the already executed processes of pre-elicitation stage. The outputs generated during elicitation processes are transferred to post-elicitation processes stage to initiate their successful launching.

4.6 PROPOSED FRAMEWORK STRUCTURAL HIERARCHY

The structural hierarchy of the proposed framework shows the linkage between requirements elicitation stages, requirements elicitation phases, requirements elicitation processes, requirements elicitation activities and requirements elicitation tasks. The main purpose of the structural hierarchical view is to show the different layers/levels of work tasks performed during the whole process of requirements elicitation using proposed framework. Consider the given figure-4.7, which shows the complete structural hierarchy of the proposed framework comprised of different stages, phases, processes, activities and tasks.

The hierarchical view of the proposed framework shows the requirements elicitation stages at the top under which different requirements elicitation phases are executed. The requirements elicitation phases are internally composed of different requirements elicitation processes. The requirements elicitation processes are internally composed of different requirements elicitation activities. The requirements elicitation activities are internally composed of different requirements elicitation tasks where requirements elicitation tasks can further be decomposed of requirements elicitation sub-tasks. The given figure shows that there are three main stages in requirements elicitation including *Elicitation Stage-1 (Pre-Elicitation Processes), Elicitation Stage-2 (Elicitation Processes)* and *Elicitation Stage-3 (Post-Elicitation Processes).*

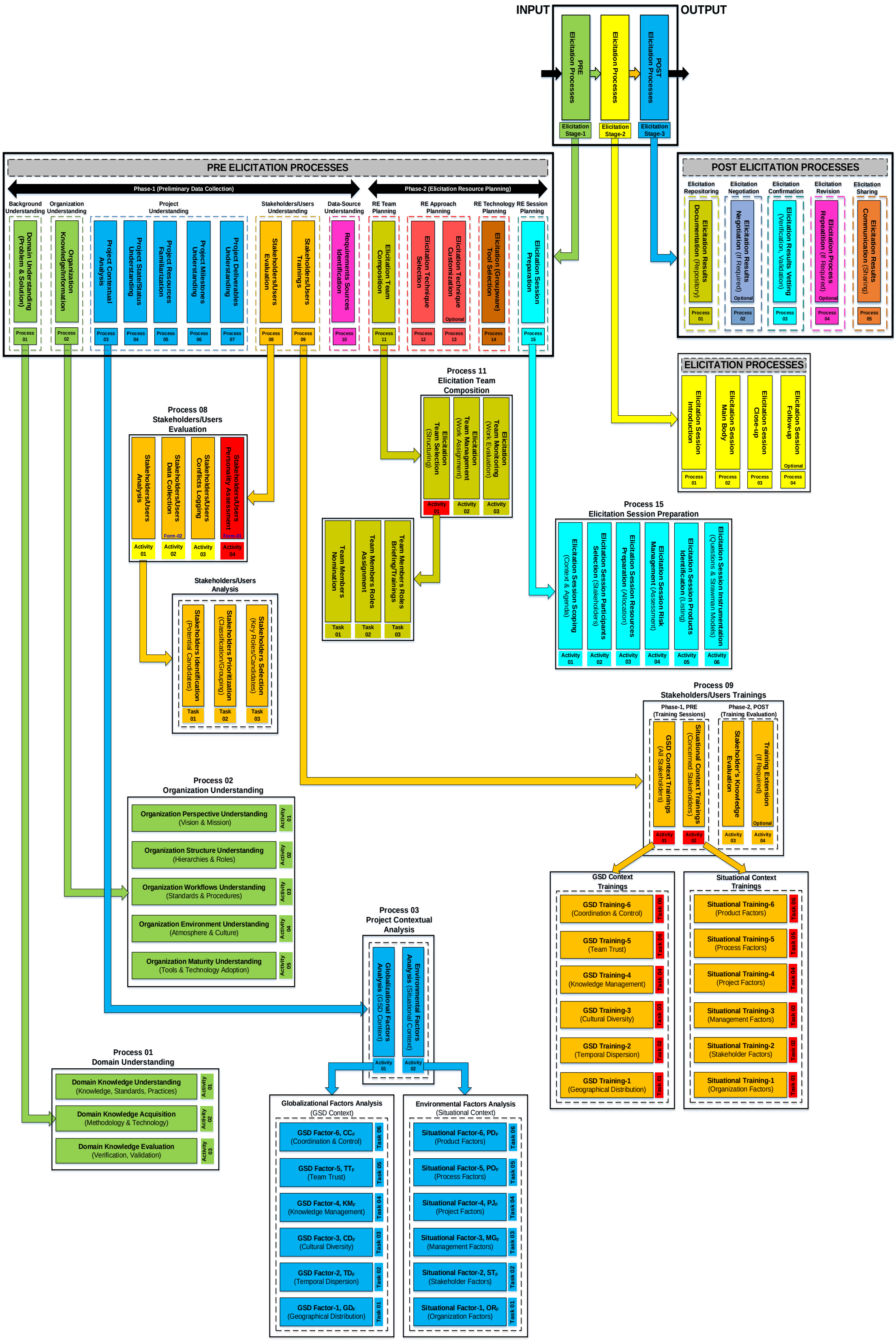


Figure-4.7 Proposed Framework Structural Hierarchy

4.6.1 Elicitation Stage-1 (Pre-Elicitation Processes)

The elicitation stage-1 is composed of two requirements elicitation phases including phase-1 (preliminary data collection) and phase-2 (elicitation resource planning). The main concern of the preliminary data collection phase is to collect the background information about the product and project using different sources of data. The main concern of the elicitation resource-planning phase is to plan the different resources required for subsequent requirements elicitation sessions.

4.6.1.1 Phase-1 (Preliminary Data Collection)

The proposed framework suggests the execution of the preliminary data collection phase at the start of the requirements elicitation to get substantial information or knowledge about the domain, organization, project, stakeholders and requirements sources. The preliminary data collection phase is comprised of following processes to get the information about different aspects of elicitation sessions:

- ***Process-1 (Domain Understanding)***

The domain understanding process is executed to get knowledge and familiarization of the problem domain and associated solution domain. The problem domain understanding can be achieved by reading different forms of documentations available as literature about problem domain knowledge and domain practices. The solution domain understanding can be achieved by considering the existing systems already available in domain as solutions for identified problems launched by other venders or competitors. There are following three main activities executed during the domain understanding process:

- Activity-1 (Domain Knowledge Understanding)
- Activity-2 (Domain Knowledge Acquisition)
- Activity-3 (Domain Knowledge Evaluation)

The activity of domain knowledge understanding refers to the information retrieval about domain basic knowledge, domain standards and domain practices. The activity of domain knowledge acquisition refers to the methodologies and technologies used to get domain information/knowledge from different sources of knowledge. The activity of domain knowledge evaluation refers to methods and techniques used for the verification and validation of the acquired domain knowledge/information.

- ***Process-2 (Organization Understanding)***

The organization understanding process is executed to get information about the client organization who is interested to use the anticipated software product. The organization understanding can be achieved by reading different organization documents like policy matters, job descriptions, organization hierarchy documents, organization working standards and strategies documents, organization rules and regulations and organization technical brochures etc. There are following five activities executed during the organization understanding process:

- Activity-1 (Organization Perspective Understanding)
- Activity-2 (Organization Structure Understanding)
- Activity-3 (Organization Workflows Understanding)
- Activity-4 (Organization Environment Understanding)
- Activity-5 (Organization Maturity Understanding)

The activity of organization perspective understanding refers to understanding the vision and mission of the client organization using vision and mission documents to get the visionary perspective of organization. The activity of organization structure understanding refers to the understanding of hierarchies and roles of the organization using organization official documentations. The activity of organization workflows understanding refers to the understanding of standards and procedures of the client organization using their official documents. The activity of organization environment understanding refers to the understanding of atmosphere and culture of client organization by observing working environments of their employees. The activity of organization maturity understanding refers to the understanding of tools and technology adoption attitude and history of the client organization by using different official documents or interviewing their employees.

- ***Process-3 (Project Contextual Analysis)***

The project contextual analysis process is executed to get the information about the context of the anticipated project. The contextual analysis of the project is carried out by executing the following two types of activities:

- Activity-1 (Globalization Factors Analysis)
- Activity-2 (Environmental Factors Analysis)

The activity of globalization factors analysis refers to the analysis of GSD factors of the anticipated project. The activity of globalization factors analysis is further composed of six different tasks including *Geographical Distribution Analysis Task, Temporal Dispersion Analysis Task, Cultural Diversity Analysis Task, Knowledge Management*

Analysis Task, Team Trust Analysis Task and Coordination & Control Analysis Task. These six tasks are carried out to get full information about the global software development factors of the project. The activity of environmental factors analysis refers to the analysis of situational factors of the anticipated project. The activity of environmental factors analysis is further composed of six different tasks including *Organization Factors Analysis Task, Stakeholders Factors Analysis Task, Management Factors Analysis Task, Project Factors Analysis Task, Process Factors Analysis Task* and *Product Factors Analysis Task.* These six tasks are carried out to get the knowledge/information about the situational context of the anticipated project.

- ***Process-4 (Project State/Status Understanding)***

The project state/status understanding process is executed to get the information about the current-status of the anticipated project. The current-status of the project may include new project, running project, halted project and partially completed project etc. Looking at the current-state of the project, the requirements elicitation team will plan the whole process of requirements elicitation.

- ***Process-5 (Project Resources Familiarization)***

The project resources familiarization process is executed to get the information about the existing resources of the project assigned by the company. The resources information is a key information that would be used to understand the project health and development constraints. The familiarization with project resources enables the requirements elicitation teams to realistically see the project constraints and plan the requirements elicitation sessions. The project resources may include the physical resources, logical resources and human resources involved for its development.

- ***Process-6 (Project Milestones Understanding)***

The project milestones understanding process is executed to get the information about the different milestones set by the developers and clients of the project. The milestones of the project refer to the different deadlines defined by the project teams to achieve certain goals of the project. The milestones help the requirements elicitation teams to plan the timelines of the requirements elicitation sessions so that to follow the overall timelines of the whole project.

- ***Process-7 (Project Deliverables Understanding)***

The project deliverables understanding process is executed to get the information about the different deliverables of the project set by the development teams and project client teams. The project deliverables can be achieved by following the already defined milestones of the project. The requirements elicitation teams can better plan the deliverables of the requirements elicitation process by considering the overall deliverables of the anticipated project.

- ***Process-8 (Stakeholders/Users Evaluation)***

The stakeholder's evaluation process is executed to get the information about the different stakeholders of the requirements elicitation process of the anticipated project. The stakeholder's evaluation process is further composed of following four activities:

- Activity-1 (Stakeholder's/User's Analysis)
- Activity-2 (Stakeholder's/User's Data Collection)
- Activity-3 (Stakeholder's/User's Conflicts Logging)
- Activity-4 (Stakeholder's/User's Personality Assessment)

The activity of stakeholder's/user's analysis refers to the identification of different types of stakeholders of the requirements elicitation process for the anticipated project. The activity of stakeholder's/user's analysis is internally composed of three tasks including *Stakeholders/Users Identification Task*, *Stakeholders/Users Prioritization Task* and *Stakeholders/Users Selection Task*. These three tasks are carried out to select the potential candidates/stakeholders of the requirements elicitation process with prioritization/ranking. The activity of stakeholder's/user's data collection refers to the information collection about the stakeholders of the requirements elicitation process. The activity of stakeholder's/user's conflict logging refers to the collection of information about the different existing conflicts of interest among the stakeholders of the requirements elicitation process. The activity of the stakeholder's/user's personality assessment refers to the personality assessment process of selected stakeholders of the requirements elicitation process using big-five personality assessment model. The stakeholder's data/information collection and personality assessment are carried out by using six different data collection forms.

- ***Process-9 (Stakeholders/Users Training)***

The stakeholders/users training process is executed to train the stakeholders of the requirements elicitation process about three main aspects of requirements elicitation, global software development and software requirements specification document preparation. After the completion of the training sessions of the selected stakeholders of the requirements elicitation process, the stakeholder's trainings evaluation is performed to assess their understanding of the project context. The stakeholder's/user's trainings process is further composed of following four different activities:

- Activity-1 (GSD Context Trainings)
- Activity-2 (Situational Context Trainings)
- Activity-3 (Stakeholders Knowledge Evaluation)
- Activity-4 (Trainings Extension)

The activity of GSD context training refers to the training of the selected stakeholders of the requirements elicitation process about the global software development factors of the project. The activity of GSD context training is composed of six different tasks including *Geographical Distribution Training Task, Temporal Dispersion Training Task, Cultural Diversity Training Task, Knowledge Management Training Task, Team Trust Training Task* and *Coordination & Control Training Task.* The activity of situational context training is composed of sex tasks including *Organizational Factors Training Task, Stakeholders Factors Training Task, Management Factors Training Task, Project Factors Training Task, Process Factors Training Task* and *Product Factors Training Task.* The activity of stakeholder's knowledge evaluation refers to the knowledge evaluation of selected stakeholders of the requirements elicitation process using different examination and assessment methods. The activity of trainings extension refers to the revision/repetition of the already given trainings to the selected stakeholders of the requirements elicitation process depending upon their knowledge evaluated using different examination methods.

- ***Process-10 (Requirements Sources Identification)***

The requirements sources identification process is executed to get the information about the different available sources of the requirements of anticipated product. The different sources of the software requirements may include stakeholders as first main source, documents as second main source, and existing systems as complementary source and domain knowledge as secondary helping source. The sources of system requirements help the requirements engineering teams to elicit the requirements of the system using different elicitation techniques and tools.

4.6.1.2 Phase-2 (Elicitation Resource Planning)

The proposed framework suggests the execution of the elicitation resource-planning phase after the completion of the preliminary data collection phase at the start of the requirements elicitation to select the appropriate requirements elicitation teams, requirements elicitation techniques and requirements elicitation groupware tools. The elicitation resource planning phases is concerned with the planning of these resources required to accomplish the requirements elicitation process successfully. The elicitation resource-planning phase is comprised of the following five processes:

- ***Process-1 (Elicitation Team Composition)***

The elicitation team composition process is concerned with the selection of the appropriate requirements elicitation teams depending upon their personality assessment information collected at the start. The elicitation team composition process is further comprised of the following three activities:

- Activity-1 (Elicitation Team Selection)
- Activity-2 (Elicitation Team Management)
- Activity-3 (Elicitation Team Monitoring)

The activity of elicitation team selection refers to the activity in which requirements elicitation team members are selected by considering the personality assessment results measured at the start of the preliminary data collection phase. The activity of elicitation team selection is further composed of three tasks including *Team Members Nomination Task, Team Members Role Assignments Task* and *Team Members Role Briefing/Training Task.* These three tasks are carried out to select the most appropriate members for the requirements elicitation teams by considering their personality traits and other relevant attributes. The activity of elicitation team management refers to team management works necessary to perform to work assignments to team members for requirements elicitation sessions. The activity of elicitation team monitoring refers to the coordination and control activities of the selected team members for the requirements elicitation process. The elicitation team monitoring activity is mainly concerned with the audit and control of assigned work tasks to different team members for requirements elicitation sessions.

- ***Process-2 (Elicitation Technique Selection)***

The elicitation technique selection process is concerned with the selection of the most suitable requirements elicitation techniques for the candidate elicitation session by considering the project context, personality traits and other relevant information. The elicitation technique selection process categorizes the different elicitation techniques according to their characteristics and considers the characteristics of the project context and user personality traits to select the most suitable requirements elicitation technique.

- ***Process-3 (Elicitation Technique Customization)***

The elicitation technique customization process is an optional process, which can be applied if desired. The elicitation technique customization process can be used to customize the selected requirements elicitation technique by considering the personality traits and other relevant attributes of the project context. This process is an optional process, which means that sometimes it may not be required to customize the selected requirements elicitation technique while in some situations it may be necessary to customize the elicitation techniques to facilitate the product users.

- ***Process-4 (Elicitation/Groupware Tool Selection)***

The elicitation tool/technology selection process is concerned with the selection of the most suitable requirements elicitation technology/tool for the candidate elicitation session by considering the project context, personality traits and other relevant information. The elicitation/groupware technology/tool selection process categorizes the different elicitation tools according to their characteristics and considers the characteristics of the project context and user personality traits to select the most suitable requirements elicitation tool.

- ***Process-5 (Elicitation Session Preparation)***

The elicitation session preparation process is concerned with the preparation of the subsequent requirements elicitation session by considering the data collected during preliminary data collection phase and elicitation resources planning phase. The elicitation session preparation process is further composed of the following six activities:

- Activity-1 (Elicitation Session Scoping)
- Activity-2 (Elicitation Session Participants Selection)
- Activity-3 (Elicitation Session Resources Preparation)
- Activity-4 (Elicitation Session Risk Management)
- Activity-5 (Elicitation Session Products Identification)
- Activity-6 (Elicitation Session Instrumentation)

The activity of elicitation session scoping refers to the elicitation session context preparation and elicitation session agenda outlining. The activity of elicitation session participant's selection refers to the process of selection of the team members for the nominated requirements elicitation session. The activity of elicitation session resources preparation refers to the process of arranging the desired physical, logical and human resources for the nominated requirements elicitation session. The activity of elicitation session risk management refers to the consideration of different risks associated with the requirements elicitation sessions and planning the sessions according to these risks. The activity of elicitation session product identification refers to the listing and analysis of the process level products of the elicitation session in form of milestones or deliverables of the candidate session. The activity of elicitation session instrumentation refers to the preparation and selection of the data collection and analysis instruments used during the requirements elicitation sessions.

4.6.2 Elicitation Stage-2 (Elicitation Processes)

The elicitation processes are concerned with the different processes that should be carried out during the requirements elicitation sessions. The elicitation processes stage is comprised of following four processes:

- ***Process-1 (Elicitation Session Introduction)***

The elicitation session introduction process is mainly concerned with introducing the requirements elicitation objectives, scope, participants, resources and instrumentations. The brief sized content brochures and other types of worm-up materials can be used to introduce the team about the desired information of the session.

- ***Process-2 (Elicitation Session Main Body)***

The elicitation session main body process is mainly concerned with the design and execution of the main contents and structure of the planned requirements elicitation session according to the available elicitation resources and elicitation context.

- ***Process-3 (Elicitation Session Close-up)***

The elicitation session close-up process is concerned with the design and planning of the elicitation session close-up activities to successfully get the desired out from the executed elicitation session.

- ***Process-4 (Elicitation Session Follow-up)***

The elicitation session follow-up process is mainly concerned with the documentation and preparation of data/guidelines about the subsequent activities that should be carried out after the completion of the planned requirements elicitation session. The elicitation follow-up is necessary to put the elicitation team in a continuous track of work and assessment of elicitation sessions to improve the outcomes of the elicitation sessions.

4.6.3 Elicitation Stage-3 (Post-Elicitation Processes)

The post-elicitation processes stage is mainly concerned with the set of those processes that should be carried out after the completion of requirements elicitation sessions. The post-elicitation processes stage is comprised of the following five processes:

- ***Process-1 (Elicitation Results Documentation)***

The elicitation results documentation process is concerned with the establishment of the elicitation results repository. This process is used to document the outcomes of the requirements elicitation sessions for their further legal use and record keeping. The elicitation results documentation process may be facilitated with certain requirements documentation template just like templates provided by IEEE to document the software requirements specifications.

- ***Process-2 (Elicitation Results Negotiation)***

The elicitation results negotiation process is used to negotiate with client or product users about the options of different features and requirements. Depending upon the negotiation outcomes, the requirements engineering team can plan the requirements prioritization process. The elicitation results negotiation process is an optional process that should be applied where it is desired otherwise it can be simply skipped to fasten the requirements elicitation process.

- ***Process-3 (Elicitation Results Vetting)***

The elicitation results vetting process is mainly concerned with the verification and validation of the results of the requirements elicitation sessions. This process is run in coordination with product users. The different requirements verification and validation techniques are available which can be applied during this process to assure the quality of the outcomes of the requirements elicitation sessions.

- ***Process-4 (Elicitation Process Repetition)***

The elicitation process repetition process is an optional process, which can be used to decide either requirements elicitation process sessions should be repeated. The repetition of the requirements elicitation sessions depends upon the quality of the outcomes of the already executed requirements elicitation sessions as well as the overall decided scope of the elicitation sessions.

- ***Process-5 (Elicitation Results Communication)***

The elicitation results communication process is mainly concerned with the sharing and communication of the outcomes of the requirements elicitation sessions. The outcomes of each executed requirements elicitation session can be shared with other team members and project management using any formal or informal data sharing mechanisms or techniques.

4.7 PROPOSED FRAMEWORK EXECUTION WORKFLOW

The proposed framework is a requirements elicitation framework for global software development teams. The design of the proposed framework is based on the top-down hierarchical structure, which decomposes a top-level abstract work-element into a bottom-level concrete work-task. Accordingly, the requirements elicitation stages are decomposed into multiple requirements elicitation phases. Similarly, the requirements elicitation phases are further decomposed into multiple requirements elicitation processes. Similarly, the requirements elicitation processes are further decomposed into multiple requirements elicitation activities. Similarly, the requirements elicitation activities are further decomposed into requirements elicitation tasks and consequential sub-tasks. A hierarchical structure is maintained in the proposed framework to accomplish the requirements elicitation process for global software development teams with more rigor and improve quality of outcomes. The execution workflow of the proposed framework shows the sequence of the execution of different processes and activities during the requirements elicitation process. Accordingly, the proposed framework execution workflow is divided into three main stages including *Elicitation Stage-1 (Pre-Elicitation Processes), Elicitation Stage-2 (Elicitation Processes)* and *Elicitation Stage-3 (Post-Elicitation Processes).*

4.7.1 Pre-Elicitation Processes Workflow

The framework starts its execution by running pre-elicitation processes before the start of the requirements elicitation sessions. The pre-elicitation processes are mainly concerned with the data collection and resource planning for the subsequent requirements elicitation sessions.

4.7.1.1 Preliminary Data Collection Processes

The pre-elicitation processes start by executing preliminary data collection processes at the starting phase of the proposed framework. The preliminary data collection processes include background understanding processes, organization understanding processes, project understanding processes, stakeholders understanding processes and data-sources understanding processes. Consider the given figure-4.8, which shows a complete vertical hierarchical structure demonstrating execution workflows sequence of these processes along with their inputs and outputs.

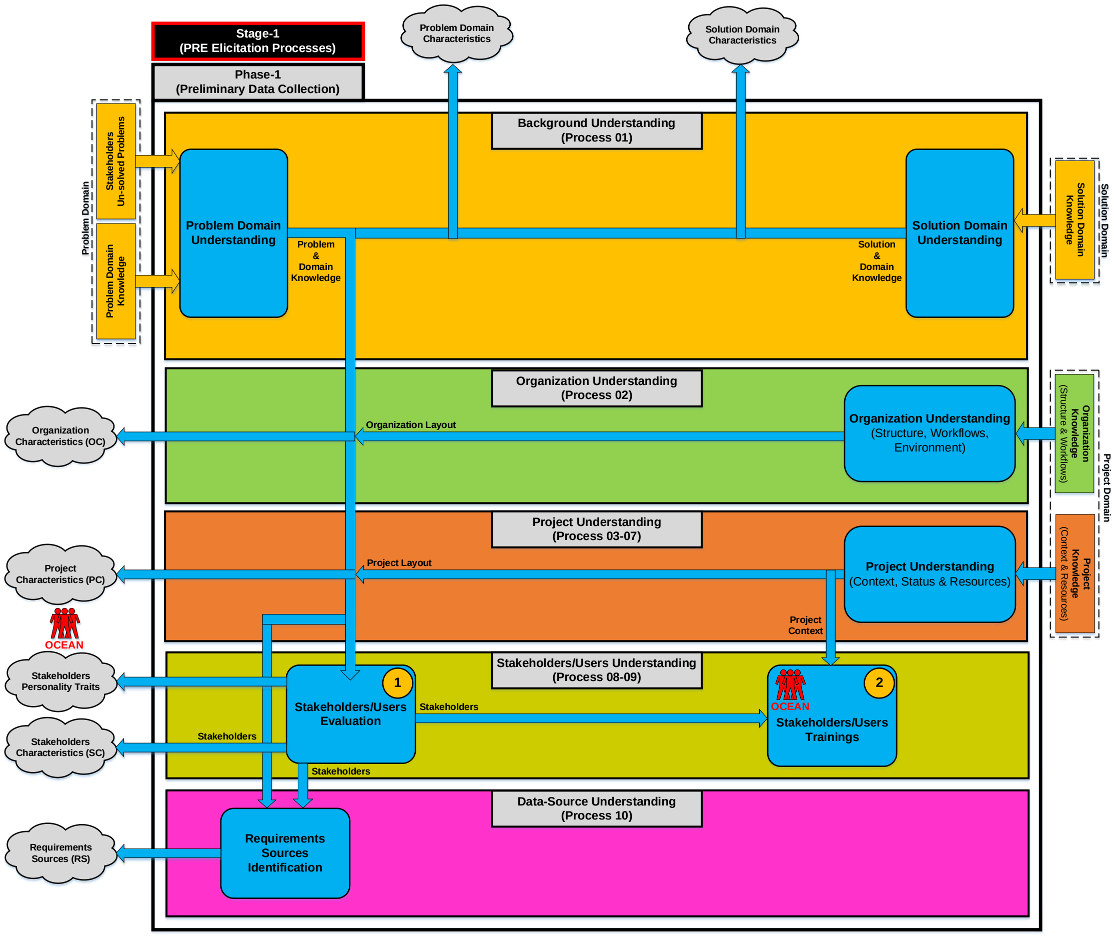


Figure-4.8 Preliminary Data Collection Processes Workflow

Background Understanding Processes are executed to get substantial background information about the anticipated project. The problem domain knowledge and the stakeholders unsolved problems become the inputs for the problem-domain understanding process while the problem domain characteristics becomes the its output. The solution domain knowledge becomes the input for the solution-domain understanding process while the solution domain characteristics becomes its outputs. There is only one process running in the domain understanding section of the proposed framework. After execution of these two processes, the requirements engineering team gets substantial background knowledge about the anticipated project which facilitates them during the requirements elicitation sessions. The problem-domain characteristics and solution domain characteristics are forwarded to other processes as background information of the project for further usage during other processes of the proposed framework.

Organization Understanding Processes are initiated to get substantial knowledge about the client organization. The organization knowledge becomes the input of the organization understanding process while the organization characteristics becomes its outputs. There is only one process running in the organization understanding section of the proposed framework. The organization understanding processes enable the requirements elicitation team to understand the basic structure or layout of the client organization. The client organization layout understanding enables the requirements engineering teams to suggest the different views of the product by considering different roles and hierarchy within the organization.

Project Understanding Processes are initiated to get substantial knowledge about the context and resources of the anticipated project. The project knowledge becomes input for these processes while the project characteristics become their output. There are a set of five different processes running in the project understanding section of the proposed framework. The different processes executing in this section include project context analysis process, project state/status understanding process, project resources understanding process, project milestones understanding process and project deliverables understanding process.

Stakeholders/Users Understanding Processes are initiated to get the substantial information about the different stakeholders of the anticipated project. There are two main processes running in this section of the proposed framework including stakeholder's evaluation process and stakeholder's trainings process. The problem-domain characteristics, solution-domain characteristic, organization characteristics and project characteristics become the inputs for the stakeholder's evaluation process while list of stakeholders, stakeholder's characteristics and stakeholder's personality traits become the outputs of this process. The project context, stakeholders list and stakeholder's personality traits become the inputs of the stakeholders training process which trains the selected stakeholders by considering their personality traits.

Data-Source Understanding Processes are initiated to get the information about the different available sources of product requirements that can be used during requirements elicitation sessions. There is only one process running in this section of the proposed framework including requirements sources identification process. The problem-domain characteristic, solution-domain characteristics, organization characteristics, project characteristics and stakeholder's characteristics become the inputs of requirements sources identification process, which gives information about the right sources of requirements as its output.

4.7.1.2 Elicitation Resource Planning Processes

The second phase of the pre-elicitation processes workflows shows the execution of elicitation resources planning processes running in the proposed framework. The elicitation resources planning processes of the proposed framework include elicitation team planning processes, elicitation technique planning processes, elicitation technology planning processes and elicitation session preparation processes. Consider the given figure-4.9, which shows the execution workflow of all these processes in form of a vertical hierarchical structure of the proposed framework.

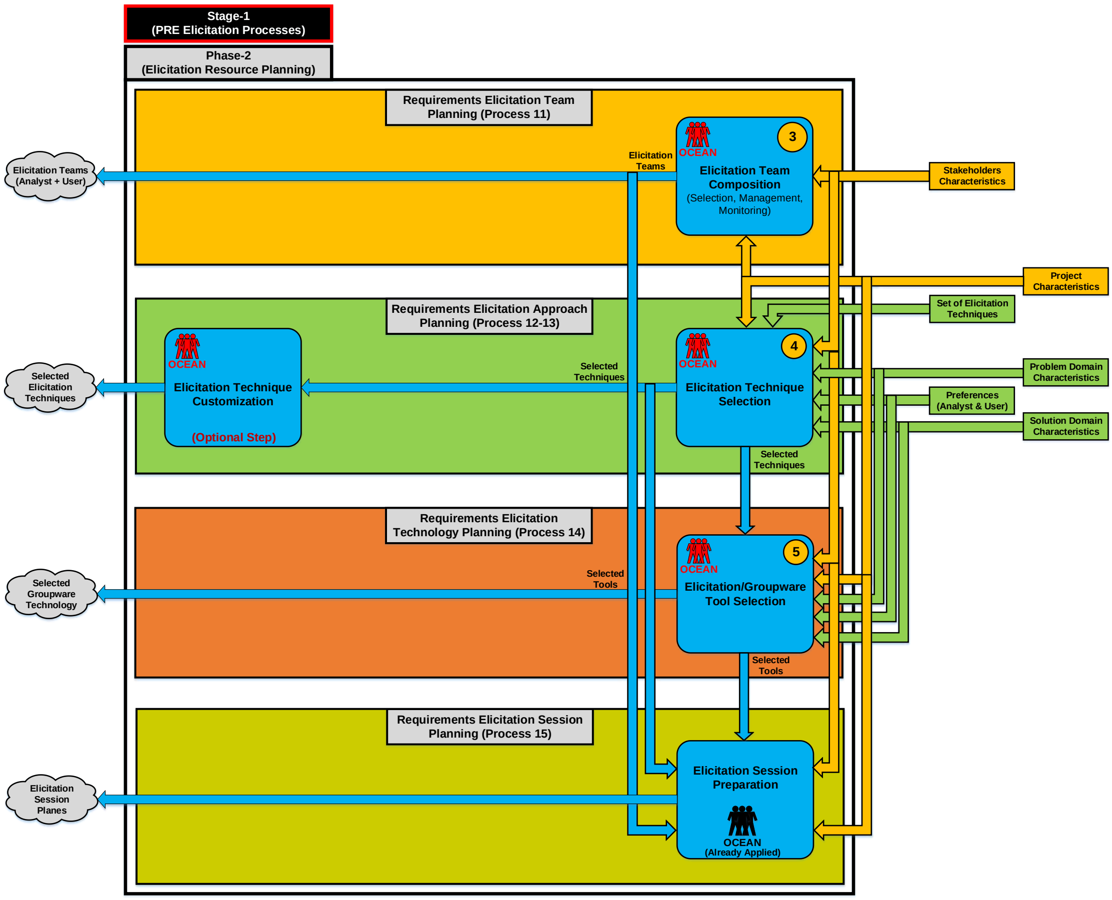


Figure-4.9 Elicitation Resource Planning Processes Workflow

Elicitation Team Planning Processes are initiated to constitute the most productive requirements elicitation teams for the requirements elicitation sessions. There is only one process running in this section of the proposed framework including elicitation team composition process. The stakeholder's characteristics, project characteristics and stakeholder's personality traits become the inputs for the elicitation team composition process while the elicitation teams (analyst team and user team) become its output. The big-five personality traits are used to select the most suitable requirements elicitation teams that would be used in the requirements elicitation sessions.

Elicitation Approach Planning Processes are initiated to select the most appropriate requirements elicitation techniques for the requirements elicitation sessions. There are two different processes running in this section of the proposed framework including requirements elicitation technique selection process and requirements elicitation techniques customization process. The project characteristics, stakeholder's characteristics, problem-domain characteristics, solution-domain characteristics, analyst and user preferences, user personality traits and set of available elicitation techniques become the inputs for the requirements elicitation technique selection process while the set of selected requirements elicitation techniques become its output. The elicitation technique customization process takes set of selected elicitation techniques as its input and generates customized elicitation techniques as its output. The requirements elicitation technique customization process is an optional process that can be used when required otherwise it can be ignored during the requirements elicitation process.

Elicitation Technology Planning Processes are initiated to select the most suitable requirements elicitation groupware technologies/tools for the requirements elicitation sessions. There is only one process running in this section of the proposed framework including elicitation/groupware tools selection process. The project characteristics, stakeholder's characteristics, problem-domain characteristics, solution-domain characteristics, analyst and user preferences, user personality traits and selected requirements elicitation techniques become the inputs for the requirements elicitation tools selection process while the set of selected requirements elicitation groupware tools become its output.

Elicitation Session Planning Processes are initiated to prepare the sufficient resources required during the requirements elicitation sessions. There is only one process running in this section of the proposed framework including elicitation session preparation process. The stakeholder's characteristics, project characteristics, selected elicitation team, selected elicitation technique and selected elicitation tool become the inputs for elicitation session preparation process while the elicitation sessions plans become its output.

4.7.2 Elicitation Processes Workflow

The elicitation processes workflow shows the set of processes executed during the requirements elicitation sessions. This phase of the proposed framework is comprised of a set of four processes including elicitation session introduction process, elicitation session main body process, elicitation session close-up process and elicitation session follow-up process. The elicitation process is executed during the requirements elicitation sessions according to the collected information during preliminary data collection phase and resources planned during the elicitation resources planning phase of the proposed framework. Consider the given figure-4.10, which shows the execution of the elicitation processes workflows and post-elicitation processes workflows in form of a vertical hierarchy of processes execution sequence.

Figure-4.10 Elicitation & Post-Elicitation Processes Workflows

4.7.3 Post-Elicitation Processes Workflow

The post elicitation processes workflow shoes the set of processes executing after the completion of the elicitation sessions. The post-elicitation processes stage is comprised of five different processes including elicitation results documentation process, elicitation results negotiation process, elicitation results vetting process, elicitation process repetition process and elicitation results communication process. The main objective of the post-elicitation processes is to formally document and share the requirements gathered during the requirements elicitation sessions. Consider the given figure, which shows the execution of the post-elicitation processes workflow in form of a vertical hierarchy of processes execution sequence.

4.8 PROPOSED FRAMEWORK PROCESSES AND ALGORITHMS

The proposed framework is integrated with five major processes and subsequent process algorithms to perform the different computations during the execution workflows for requirements elicitation processes. The integrated processes and algorithms of proposed framework are formulated by using big-five personality traits assessment procedures. The different processes integrated inside the proposed framework for the requirements elicitation process include requirements elicitation stakeholder's analysis process, requirements elicitation stakeholder's training process, requirements elicitation team selection process, requirements elicitation technique selection process and requirements elicitation groupware tools selection process. The complete details of all these processes are given in the subsequent sections to explain their role in the proposed framework.

4.8.1 Stakeholders Analysis Process

The requirements elicitation stakeholder's analysis process is concerned with the profiling, identification, prioritization and selection of requirements elicitation stakeholders. Consider the given figure-4.11, which explains the complete details of different stages/steps and subsequent functions performed by this process during the requirements elicitation process defined by the propose framework.

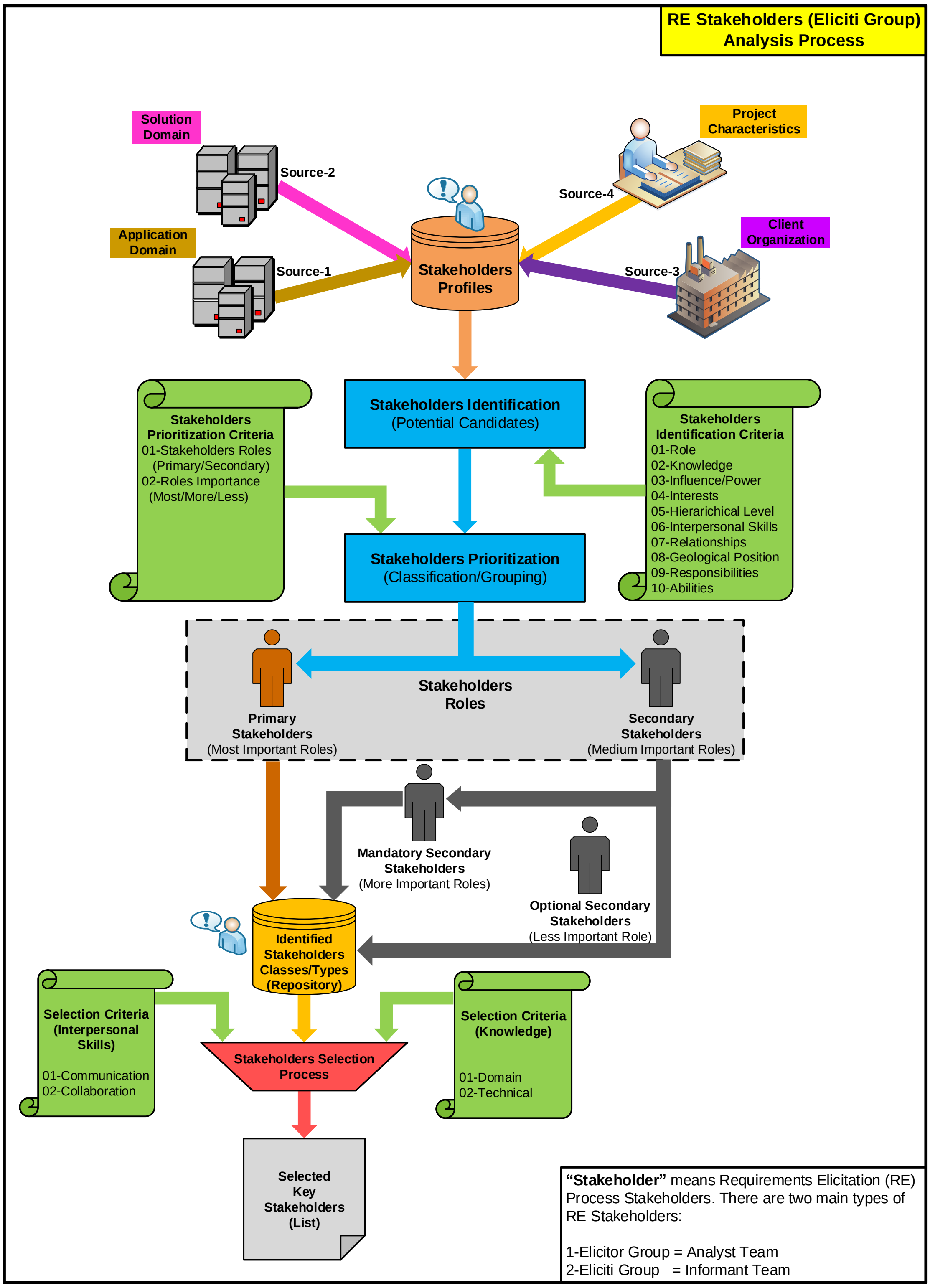


Figure-4.11 RE Stakeholders Analysis Process

It can be seen from the given figure that stakeholder's analysis process computes the stakeholder's profiles at the start of this analysis process. The stakeholder's analysis process categorizes four major sources of the requirements elicitation stakeholders including *Source-1 (Application Domain)*, *Source-2 (Solution Domain)*, *Source-3 (Client Organization)* and *Source-4 (Project Characteristics).* The first source is application domain, which refers to the problem domain of the anticipated product. The second source is solution domain, which usually refers to the technological solution provided by the developer company to product users. The third source is client organization, which refers to the organizational details of the customer/client for which the anticipated product is developed. The information about the client organizational roles and hierarchies helps the developers to create suitable user views in the product. The fourth source is project characteristics, which defines the all features and characteristics of the anticipated project. The project characteristics also help us to identify different roles involved in the development of the product.

The information from the stakeholder's profiles is used to perform the stakeholder's identification step of the stakeholder's analysis process. The stakeholder's identification step is performed to identify the potential candidates for stakeholder's roles. There are a pre-defined stakeholder's identification criteria, which is used to identify the potential candidates for stakeholder's role. The stakeholder's identification criteria are based on ten different attributes including role, knowledge, influence/power, interests, hierarchical level, interpersonal skills, relationships, geological position, responsibilities and abilities. These pre-defined stakeholder's selection criteria attributes are used to select the most appropriate stakeholders of the anticipated product and project to engage them for requirements elicitation process.

After the completion of the stakeholder's identification step, the information about the candidate stakeholders is used by the next step of stakeholder's prioritization. The main function of stakeholder's prioritization step is to categorize/classify different stakeholders into different related groups. There is a pre-defined criterion, which is used during stakeholder's prioritization step. The stakeholder's prioritization criteria are based on two main attributes including stakeholder's roles (primary/secondary) and roles importance (most/more/less). Hence, the stakeholder's prioritization step categorizes the product stakeholders into two main types include primary stakeholders (have most important role) and secondary stakeholders (have medium important role). The secondary stakeholders are further categorized/divided into two sub-groups including mandatory secondary stakeholders (have more important roles) and optional stakeholders (have less important role). The detailed information about all these three types of stakeholders are sent to stakeholder's repository, which maintains the information of stakeholder's classes/types.

The stakeholder's analysis process runs the stakeholder's selection step at the end to select the most suitable stakeholders of the product/project by using a pre-defined stakeholders selection criterion. The stakeholder's selection criteria are based on two main attributes of stakeholder's knowledge and stakeholder's interpersonal skills. The stakeholder's knowledge criteria are based on two attributes of stakeholder's domain knowledge and technical knowledge. Similarly, the stakeholder's interpersonal skills criteria are based on two attributes of stakeholder's communication skills and stakeholder's collaboration skills. Hence, the stakeholder's selection step uses these attributes of stakeholder's knowledge and interpersonal skills to select the different key stakeholders for requirements elicitation process.

4.8.2 Stakeholder's Training Process

The stakeholders training may include two broad categories of trainings including traditional trainings about situational context of the project and specific trainings about globalization context of the project. There is no need to define some specific format of process for the situational context trainings, which train the participants of requirements elicitation process about the requirements elicitation, requirements documentation and other project related aspects. The companies may define their own methodologies for giving the traditional trainings about project related aspects and requirements elicitation process and documentation related context.

Although, there is no need to define some fixed pattern for the execution of training programs for traditional situational context trainings, but there is a need to define a systematic process for the trainings of the stakeholders about the globalization context. Since the proposed framework is designed for the geologically distributed teams, there is a need to define a personality-oriented training process, which should train the stakeholders about three main challenging aspects of global software development including temporal diversity, cultural diversity and linguistic diversity. Hence, the globalization aspects trainings given to the selected stakeholders are comprised of three main parts including temporal diversity training, cultural diversity training and linguistic diversity training. Consider the given figure-4.12, which shows a complete design of globalization aspects training process for selected stakeholders of the requirements elicitation process.

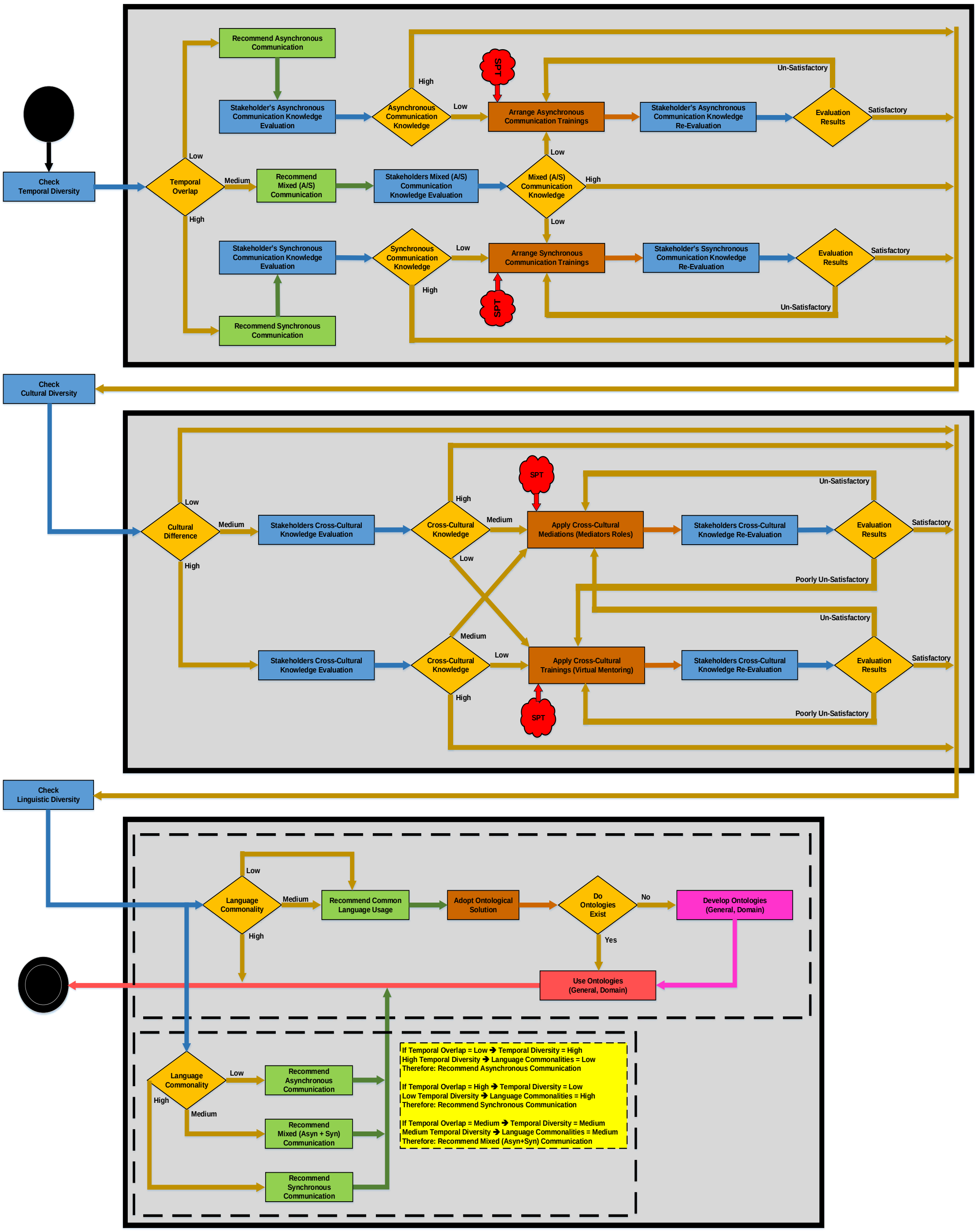


Figure-4.12 RE Stakeholder's Trainings Process

4.8.2.1 Temporal Diversity Training

The stakeholder's GSD context trainings start with first layer of trainings about the temporal dispersion factor, which is based on the temporal overlap between the stakeholders. The temporal diversity trainings train the stakeholders about the different effects of temporal diversity among the requirements elicitation teams and different working patterns that can be adopted in different temporal dispersion scenarios. It can be seen from the given figure that training process starts and initially checks the temporal diversity of stakeholders to decide the training modes and training contents. The stakeholder’s temporal overlaps can be categorized into three main types including low temporal overlap, medium temporal overlap and high temporal overlap.

Low Temporal-Overlap: If the temporal overlap between stakeholders is low, recommend the stakeholder to use asynchronous communications like emails, mailing lists, news groups, and asynchronous shared whiteboards and discussion forums. Accordingly, evaluate the knowledge of the stakeholders about the asynchronous communications. If the stakeholder’s knowledge about the asynchronous communications is already high, then there is no need to give them any trainings on asynchronous communications. If the stakeholder’s knowledge about the asynchronous communications is low, then arrange asynchronous communications trainings. During the asynchronous trainings, use the stakeholder’s personality traits to customize the training sessions to facilitate the involved stakeholders. After the completion of the training sessions, re-evaluate the stakeholder’s knowledge about the asynchronous communications. If the stakeholder’s knowledge about the asynchronous communications is satisfactory, then do not repeat this training and hence go to next category of trainings. However, if the stakeholder’s knowledge about the asynchronous communications is unsatisfactory, then keep on repeating this training until you get the stakeholders satisfactory results.

Medium Temporal-Overlap: If the temporal overlap between stakeholders is medium, recommend the stakeholder to use mixed communications (asynchronous & synchronous). Accordingly, evaluate the knowledge of the stakeholders about the mixed communications. If the stakeholder's knowledge about the mixed communications is already high, then there is no need to give them any trainings on mixed communications. If the stakeholder's knowledge about the mixed communications is low, then arrange asynchronous communications trainings as well as synchronous communications trainings. During the trainings, use the stakeholder's personality traits to customize the training sessions to facilitate the involved stakeholders. After the completion of the training sessions, re-evaluate the stakeholder's knowledge about the mixed communications. If the stakeholder's knowledge about the mixed communications is satisfactory, then do not repeat this training and hence go to next category of trainings. However, if the stakeholder's knowledge about the mixed communications is unsatisfactory, then keep on repeating this training until you get the satisfactory results from stakeholders.

High Temporal-Overlap: If the temporal overlap between stakeholders is high, recommend the stakeholder to use synchronous communications like instant messaging, synchronous shared whiteboards, chats and video-conferencing. Accordingly, evaluate the knowledge of the stakeholders about the synchronous communications. If the stakeholder's knowledge about the synchronous communications is already high, then there is no need to give them any trainings on synchronous communications. If the stakeholder's knowledge about the synchronous communications is low, then arrange synchronous communications trainings. During the synchronous communication trainings, use the stakeholder's personality traits to customize the training sessions to facilitate the involved stakeholders. After the completion of the training sessions, re-evaluate the stakeholder's knowledge about the synchronous communications. If the stakeholder's knowledge about the synchronous communications is satisfactory, then do not repeat this training and hence go to next category of trainings. However, if the stakeholder's knowledge about the synchronous communications is unsatisfactory, then keep on repeating this training until you get the stakeholders satisfactory results.

4.8.2.2 Cultural Diversity Training

After the completion of the temporal diversity training sessions, the cultural diversity of the stakeholders is checked. The cultural diversity of stakeholders can be categorized into three main types including low cultural diversity, medium cultural diversity and high cultural diversity. The cultural diversity directly affects the interpersonal skills like communicational skills and collaboration skills along with working aptitudes of participants.

Low Cultural-Diversity: If the cultural diversity of stakeholders is low, then there is no need to give any trainings about cultural diversity aspects and their effects on team works. In this scenario, the trainings are bypassed and process moves on the next stage of trainings, which involve the trainings about linguistic diversity.

Medium Cultural-Diversity: If the cultural diversity of the stakeholders is medium, then evaluate the knowledge of stakeholders about cross-cultures. If the stakeholder's knowledge about cross-cultures is already high, then there is no need to give them any training about cross-cultural aspects. However, if the stakeholder's knowledge about cross-cultures is medium, then apply the cross-cultural mediations (mediator's roles) for stakeholder's trainings. Again, re-evaluate the knowledge of stakeholders about the cross-culture. If the stakeholder's knowledge about cross-culture is satisfactory, then there is no need to repeat this training. If the stakeholder's knowledge about the cross-culture is unsatisfactory, then repeat cross-cultural mediations until you get the satisfactory results. If the stakeholder's knowledge about cross-culture is poorly unsatisfactory, then apply cross-cultural trainings (virtual mentoring) and re-evaluate the stakeholder's knowledge about cross-cultures. Similarly, if the stakeholder's knowledge about the cross-culture is low, then apply cross-cultural trainings using virtual mentoring and re-evaluate the stakeholder's knowledge accordingly.

High Cultural-Diversity: If the cultural diversity of the stakeholders is high, then evaluate the knowledge of stakeholders about cross-cultures. If the stakeholder's knowledge about cross-cultures is already high, then there is no need to give them any training about cross-cultural aspects. However, if the stakeholder's knowledge about cross-cultures is medium, then apply the cross-cultural mediations (mediator's roles) for stakeholder's trainings and re-evaluate them accordingly. However, if the stakeholder's knowledge about the cross-culture is low, then apply cross-cultural trainings using virtual mentoring and re-evaluate the stakeholder's knowledge. Use user's personality traits to customize the trainings sessions to facilitate the participants. Again, re-evaluate the stakeholder's cross-cultural knowledge and keep on repeating or skipping the training sessions as was in case of medium cultural diversity.

4.8.2.3 Linguistic Diversity Training

After the completion of the cultural diversity trainings, the linguistic diversity of the stakeholders is checked to see the language commonalities among the stakeholders. If the language commonalities among the stakeholders is high, then there is no need to do anything but simply finish the process. However, if the language commonalities are low or medium, then recommend the common language usage and adopt ontological solutions. If the ontologies already exist, then simply use these ontologies and finish the process. However, if the ontologies do not exist, then develop the required ontologies and then use these ontologies and finish the process. Also, if the language commonalities are high, then recommend the use of synchronous communications. If the language commonalities are low, then recommend the use of asynchronous communications. If the language commonalities are medium, then recommend the use of mixed communications.

4.8.3 Team Selection Process

The requirements elicitation team selection process is used to select the appropriate members of the requirements elicitation process by considering their personality traits. The requirements elicitation team is comprised of two sub-teams including analyst team and user team. There is no need to devise any process for selection of user teams because the proposed framework successfully works with any type of personality traits found within user teams. However, there is need to devise a personality traits-based process that can be used to select the most appropriate software development teams including requirements engineering/analyst team, software design team, software implementation team and software testing team. Therefore, a systematic team selection process is presented in this section, which has been successfully applied to select the requirements analyst team for requirements elicitation process.

4.8.3.1 Personality Traits Based Team Selection Process

The personality traits-based team selection process is comprised of ten different stages/steps that collectively enable the software companies to select the most appropriate software teams according to their role in software development lifecycle. These ten stages/steps used by this team selection process are explained in subsequent section.

Step-01 (Select Software Development Team Role)

Select the software development stage (software developer's role) for selection of a suitable development team.

Step-02 (Select Personality Assessment Model)

Choose an appropriate personality assessment model (like Big-Five, MBTI and KTS etc.) as reference model for team selection process.

Step-03 (List Personality Traits of Selected Model)

Select the prescribed personality traits of selected personality assessment model.

Step-04 (Define Personality Facets for Each Listed Trait)

Define the low and high characteristics of each trait of selected personality assessment model as its facets. Use the following tabular format to present facets of traits. Consider table-4.1 for details.

Table-4.1 Personality Facets for Selected Personality Traits

Personality Model	Personality Trait	Trait Short Description	Low Facets	High Facets
Model Title	T1	Short Description …	Facet-L1	Facet-H1
	T2	Short Description …	Facet-L2	Facet-H2
	T3	Short Description …	Facet-L3	Facet-H3
	.	.	.	.
	T_K	Short Description …	Facet-L_K	Facet-H_K

Step-05 (Assign Code to Each Job Descriptions of Selected Team Role)

Use the following tabular format to list down all possible job tasks/descriptions of selected software development team role as found in industry job portals, news or survey. Assign unique codes to each job descriptions for its further use in computations. Consider table-4.2 for details.

Table-4.2 Job Descriptions Advertised for Selected Role

S#	Software Development "Role" Job Descriptions Advertised by Software Industry	Assigned Code
1	Job Description …	JD_1
2	Job Description …	JD_2
3	Job Description …	JD_3
.	.	.
M	Job Description …	JD_M

Step-06 (Assign Code to Each Essential Soft Skill of Selected Team Role)

Use the following tabular format to list down essential soft skills (ESS) of selected software development role as found in industry job portals, news or survey. Assign unique codes to each essential soft skill for its further use in computations. Consider table-4.3 for details.

Table-4.3 Soft Skills Required in Software Developers

S#	Software Development "Role" Essential Soft Skills Advertised by Software Industry	Assigned Code
1	Essential Soft Skill …	ESS_1
2	Essential Soft Skill …	ESS_2
3	Essential Soft Skill …	ESS_3

.	.	.
N	Essential Soft Skill …	ESS_N

Step-07 (Relate Each ESS with Personality Characteristics and Traits)

Use the following tabular format to relate each ESS with personality characteristics. Use traits facets to relate personality traits of selected personality assessment model with these personality characteristics. Consider table-4.4 for details.

Table-4.4 Relating Essential Soft Skills with Selected Traits

Essential Soft-Skills	Related Personality Characteristics	Related Personality Trait
ESS_1	Personality Characteristics …	Personality Trait…
ESS_2	Personality Characteristics …	Personality Trait…
ESS_3	Personality Characteristics …	Personality Trait…
.	.	.
ESS_N	Personality Characteristics …	Personality Trait…

Step-08 (Map ESSs on JDs of Selected Role to Find Net-ESS)

Use the following tabular format to map each essential soft skill on each job description of the selected role. Find the Net Essential Soft Skills Distribution for each ESS mapped on all JDs as Net-ESS. Consider table-4.5 for details.

Table-4.5 Mapping Essential Soft Skills with Job Descriptions

Selected Role JD	Needed "Essential Soft Skills"				
	ESS_1	**ESS_2**	**ESS_3**	**…**	**ESS_N**
JD_1	Yes/No	Yes/No	Yes/No	…	Yes/No
JD_1	Yes/No	Yes/No	Yes/No	…	Yes/No
JD_1	Yes/No	Yes/No	Yes/No	…	Yes/No
.	.	.	.	.	.
JD_M	Yes/No	Yes/No	Yes/No	…	Yes/No
Net ESS Distribution	Net-ESS_1	Net-ESS_2	Net-ESS_3	…	Net-ESS_N

Step-09 (Draw Net-ESS in Table in Descending Order)

Use the following tabular format to place Net-ESS in a descending order along with their related personality trait. Consider table-4.6 for details.

Table-4.6 Net ESS and Related Personality Traits

All Net-ESS Values Drawn in Descending Order			
Net-ESS	Highest Net-ESS Values	. . . . .	Lowest Net-ESS Values
Related Personality Trait	Personality Trait	. . . . .	Personality Trait

Step-10 (Accumulate Personality Traits to Find Their Ranking)

Use the following tabular format to find the accumulated ranking of personality traits by taking union of similar personality traits across their appearance in frequency distributions. Consider table-4.7 for details.

Table-4.7 Recommended Personality Traits for Selected Role

Ranking Personality Traits (Highest to Lowest)		
Highest Personality Trait	. . . .	**Lowest Personality Trait**
Personality Trait (Net-ESS/Total JDs)	. . . .	Personality Trait (Net-ESS/Total JDs)

4.8.3.2 RE Team Selection Process Example

Here is a solved scenario of team selection process where the requirements analyst team is selected by considering the personality traits required for the role of requirements engineer/analyst.

Step-01 (Select Software Development Team Role)

Team Role: Requirements Analyst

Step-02 (Select Personality Assessment Model)

Personality Model: Big-Five Assessment Model

Step-03 (List Personality Traits of Selected Model)

Personality Traits: Openness, Conscientious, Extroversion, Agreeableness, Neuroticism

Step-04 (Define Personality Facets for Each Listed Trait)

Consider table-4.8 for details.

Table-4.8 Personality Facets for Big-Five Traits

Personality Model	Personality Trait	Trait Short Description	Low Facets	High Facets
Big-Five Traits	Openness	Explorer Vs Preserver	Closed-minded, Traditional, Conservative, Shallow, Conforming	Curious, Intellectual, Imaginative, Creative, Innovative, Flexible/Open-minded
	Conscientiousness	Focused Vs Flexible	Disorganized, Inefficient, Lazy, Irresponsible, Careless	Hardworking, Disciplined, Organized, Responsible, Efficient
	Extroversion	Extrovert Vs Introvert	Quiet, Reserved, Private, Shy, Unadventurous	Sociable, Talkative, Assertive, Dominant, Energetic
	Agreeableness	Adapter Vs Challenger	Quarrelsome, Rude, Selfish, Un-cooperative, Un-kind	Kind, Sympathetic, Helpful, Cooperative, Forgiving

	Neuroticism	Reactive Vs Resilient	Calm, Self-confident, Stable, Secure, Relaxed, Fearless	Anxious, Emotional, Nervous, Insecure, Fearful

Step-05 (Assign Code to Each Job Descriptions of Selected Team Role)

Consider table-4.9 for details.

Table-4.9 Job Descriptions Advertised for Requirements Engineer
(Capretz & Ahmed, 2010), (Rehman, Mahmood & Salleh, 2012)

S#	Software Development "Requirements Analyst" Job Descriptions Advertised by Software Industry	Assigned Code
01	Extensive liaison with clients	**JD-01**
02	Client's existing systems analysis	**JD-02**
03	Client's requirements translation into project briefs	**JD-03**
04	Potential solutions identification and assessment	**JD-04**
05	Proposing logical and innovative system solutions for users	**JD-05**
06	Suggesting proposals for system modifications/replacements	**JD-06**
07	Working on system/software feasibility reports	**JD-07**
08	Working with developers and users to build a product	**JD-08**
09	Supervising new system development	**JD-09**
10	Keeping work aligned with planned deadlines	**JD-10**
11	Maintain updated knowledge about industry practices	**JD-11**

Step-06 (Assign Code to Each Essential Soft Skill of Selected Team Role)

Consider table-4.10 for details.

Table-4.10 Soft Skills Required in Software Developers
(Capretz & Ahmed, 2010), (Rehman, Mahmood & Salleh, 2012)

S#	Software Development Essential Soft Skills Advertised by Software Industry	Assigned Code
01	Communication Skills	**ESS-01**
02	Interpersonal Skills	**ESS-02**
03	Analytical & Problem-Solving Skills	**ESS-03**
04	Open And Adaptable To Changes	**ESS-04**
05	Organizational Skills	**ESS-05**
06	Team Player Skills	**ESS-06**
07	Ability To Work Independently	**ESS-07**
08	Active Listener Skills	**ESS-08**
09	Innovative Mind	**ESS-09**
10	Pay Through And Acute Attention To Details	**ESS-10**

11	Fast Learner Skills	**ESS-11**

Step-07 (Relate Each ESS with Personality Characteristics and Traits)

Consider table-4.11 for details.

Table-4.11 Relating Essential Soft Skills with Big-Five Traits

(Capretz & Ahmed, 2010), (Rehman, Mahmood & Salleh, 2012)

Essential Soft-Skills	Related Personality Characteristics	Related Big-Five Trait
ESS-01	Sociable, Talkative	Extraversion
ESS-02	Sociable, Talkative	Extraversion
ESS-03	Solution Oriented, Analytical	Openness
ESS-04	Enquiring, Curious, Willing to Learn	Openness
ESS-05	Organized, Responsible, Business like	Conscientiousness
ESS-06	Helpful, Unselfish, Cooperative	Agreeableness
ESS-07	Imaginative, Intelligent, Analytical	Openness
ESS-08	Sociable, Interactive	Extraversion
ESS-09	Creative, Inventive, Innovative	Openness
ESS-10	Analytical, Investigative	Openness
ESS-11	Curious, Willing to Learn	Openness

Step-08 (Map ESSs on JDs of Selected Role to Find Net-ESS)

Consider table-4.12 for details.

Table-4.12 Mapping Essential Soft Skills with Job Descriptions for Analyst

Analyst JD	**Needed "Essential Soft Skills"**										
	ESS 01	**ESS 02**	**ESS 03**	**ESS 04**	**ESS 05**	**ESS 06**	**ESS 07**	**ESS 08**	**ESS 09**	**ESS 10**	**ESS 11**
JD-01	Yes	Yes	-	-	-	-	-	Yes	-	-	-
JD-02	-	-	Yes	-	-	-	-	-	-	Yes	Yes
JD-03	Yes	Yes	-	-	-	-	-	-	-	-	-
JD-04	-	-	-	-	-	-	-	-	Yes	Yes	-
JD-05	-	-	Yes	-	-	-	-	-	Yes	Yes	-
JD-06	Yes	-	-	Yes	-	-	-	-	-	-	-
JD-07	Yes	-	-		-	-	-	-	-	-	-
JD-08	Yes	Yes	-	Yes	-	Yes	-	Yes	-	-	-
JD-09	-	Yes	-	-	Yes	-	-	-	-	-	-
JD-10	-	-	-	Yes	Yes	-	Yes	-	-	-	-
JD-11	-	-	-	Yes	Yes	-	-	-	-	-	-
Net ESS Dist.	**5**	**4**	**2**	**4**	**3**	**1**	**1**	**2**	**2**	**3**	**1**

Step-09 (Draw Net-ESS in Table in Descending Order)
Consider table-4.13 for details.

Table-4.13 Net ESS and Related Personality Traits of Requirements Analyst

All Net-ESS Values Drawn in Descending Order					
Net-ESS	**ESS-01 = 5**	**ESS-02 = 4** **ESS-04 = 4**	**ESS-05 = 3** **ESS-10 = 3**	**ESS-03 = 2** **ESS-08 = 2** **ESS-09 = 2**	**ESS-06 = 1** **ESS-07 = 1** **ESS-11 = 1**
Related Personality Trait	Extraversio n	Extraversion Openness	Conscienti ousness Openness	Openness Extraversio n Openness	Agreeablen ess Openness Openness

Step-10 (Accumulate Personality Traits to Find Their Ranking)
Consider table-4.14 for details.

Table-4.14 Recommended Personality Traits for Requirements Analyst

Ranking of Recommended Personality Traits for Requirements Engineers					
Trait Frequency	**Highest Trait**	**Intermediate Traits**		**Lowest Trait**	**N. A Trait**
Trait (Net-ESS/JDs)	Openness (7/11)	Extraversi on (6/11)	Conscientio usness (3/11)	Agreeable ness (1/11)	Neuroticis m (0/11)

4.8.4 Technique Selection Process

The requirements elicitation technique selection process initially performs the techniques classifications and then performs the elicitation techniques selection depending upon the project based environmental factors and globalization factors. Some other external project attributes may affect the process of requirements elicitation techniques selection. The requirements elicitation technique selection process of the proposed framework also considers all these external factors during the selection process. Therefore, the requirements elicitation techniques selection process is divided into four main phases including RE techniques classification, RE techniques factors analysis, RE techniques mapping with personality traits and RE techniques selection process structure.

4.8.4.1 Techniques Classification

The requirements elicitation technique selection process classifies the different requirements elicitation techniques into four major groups including *Conversational (CON)* methods, *Observational (OBS)* methods, *Analytical (ANA)* methods and *Synthetic (SYN)* methods, depending on their characteristics. The requirements elicitation techniques are further classified as group-based techniques and non-group-based techniques. The conversation requirements elicitation techniques may be non-group based like interviews as well as group-based like group meetings, focus groups, workshops, brainstorming etc. Similarly, other requirements elicitation techniques can also be divided as group-based or non-group based. The short descriptions of each type of elicitation techniques is given in this section.

The ***Conversational Methods*** are also known as verbal methods and provide a means of verbal communication between participants. The conversational methods are commonly based on question-answer mechanisms to extract the knowledge. The conversational methods may include interviews, questionnaires/surveys, workshops, brainstorming, focus groups and group meetings etc. The ***Observational Methods*** provide a means to develop a rich understanding of the application domain by observing human activities. Consequently, observing how people perform their routine-work facilitates information gathering which may be challenging to explain in words. The observational methods may include observations (active, passive and explorative), ethnomethodology, protocol analysis and apprenticing methods etc. The ***Analytic***

Methods are also known as cognitive methods and provide ways to explore the existing documentations and acquire requirements from a series of deductions. The analytical methods may include requirement reuse, domain analysis, background reading, laddering, card sorting, repertory grids, mind mapping, introspection discourse analysis (using conversation analysis and speech act analysis). The ***Synthetic Methods*** incorporate various channels of communication and offer models to illustrate the characteristics and relationship of system. They deliver good hints for requirements recognition, in the form of abundant semantic models. The synthetic methods may include scenarios, storyboarding, prototyping, joint application development (JAD) or rapid application development (RAD), contextual inquiry, role-playing and appreciative inquiry etc.

4.8.4.2 Techniques Factors Analysis

The requirements elicitation technique selection process initially defines a set of external factors that may affect the requirements elicitation technique selection process. In case of requirements elicitation process executing in global software development projects, the requirements elicitation technique selection process depends on a diver set of environmental and globalization factors. The requirements elicitation techniques selection process depends on seven different factors. These classes of factors include problem-domain factors, solution-domain factors, project-domain factors, user/developer team's factors, global software development domain factors, requirements engineering domain factors and psychology domain factors. Consider the given figure-4.13, which displays all these factors as a circular chart by grouping each of these factors according to their nature. The problem-domain factors include the problem-domain characteristics (problem attributes/features). The solution-domain factors include the solution-domain characteristics (domain attributes/features).

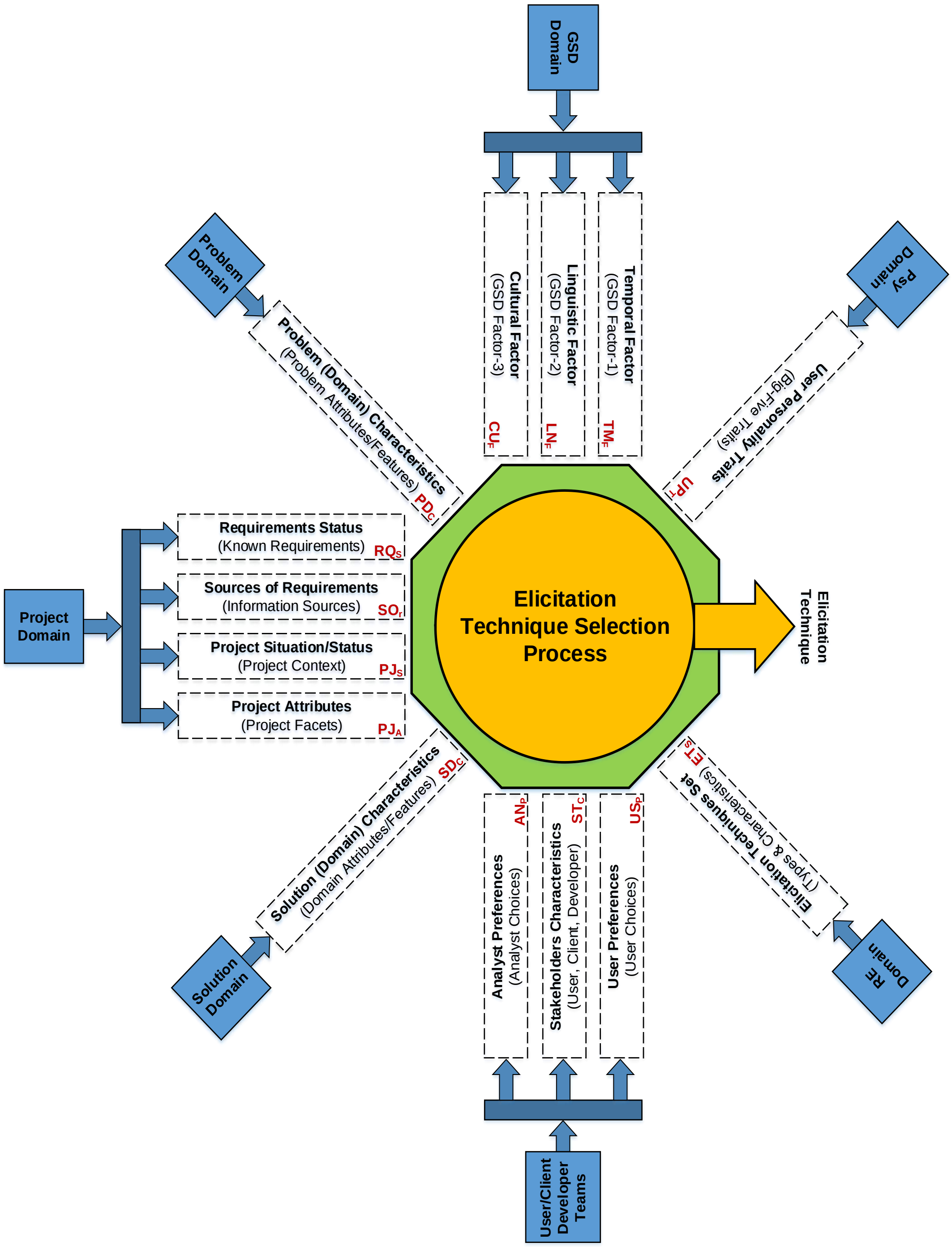


Figure-4.13 Factors for RE Techniques Selection Process

The project-domain factors include the requirements status (known requirements), the sources of requirements (information sources), the project status/situation (project context) and the project attributes (project facets). The user/developer team's factors include the stakeholder's characteristics (user, client and developers etc.), the analyst preferences (analyst choices) and the user preferences (user choices). The global software development domain factors include the temporal factors, the cultural factors and the linguistic factors. The requirements engineering domain factors include the elicitation techniques set (types and characteristics). The psychology domain factors include the user personality traits (big-five traits).

4.8.4.3 Techniques Mapping with Personality Traits

The big-five personality traits of the users are systematically mapped on the different classes/categories of the requirements elicitation techniques. The requirements elicitation techniques are classified into four major categories of conversational techniques, observation techniques, analytical techniques and synthetic techniques. These four classes/categories of requirements elicitation techniques are further divided into two main groups of group-based elicitation techniques and non-group-based elicitation techniques. In the first stage of mapping, the big-five personality traits of users are mapped on four classes (conversational, observational, analytical and synthetic) of the elicitation techniques. In the second stage of mapping, the big-five personality traits of users are mapped on two classes (group-based techniques and non-group-based techniques). Consider the given figure-4.14, which shows the complete process of requirements elicitation techniques mapping with big-five personality traits.

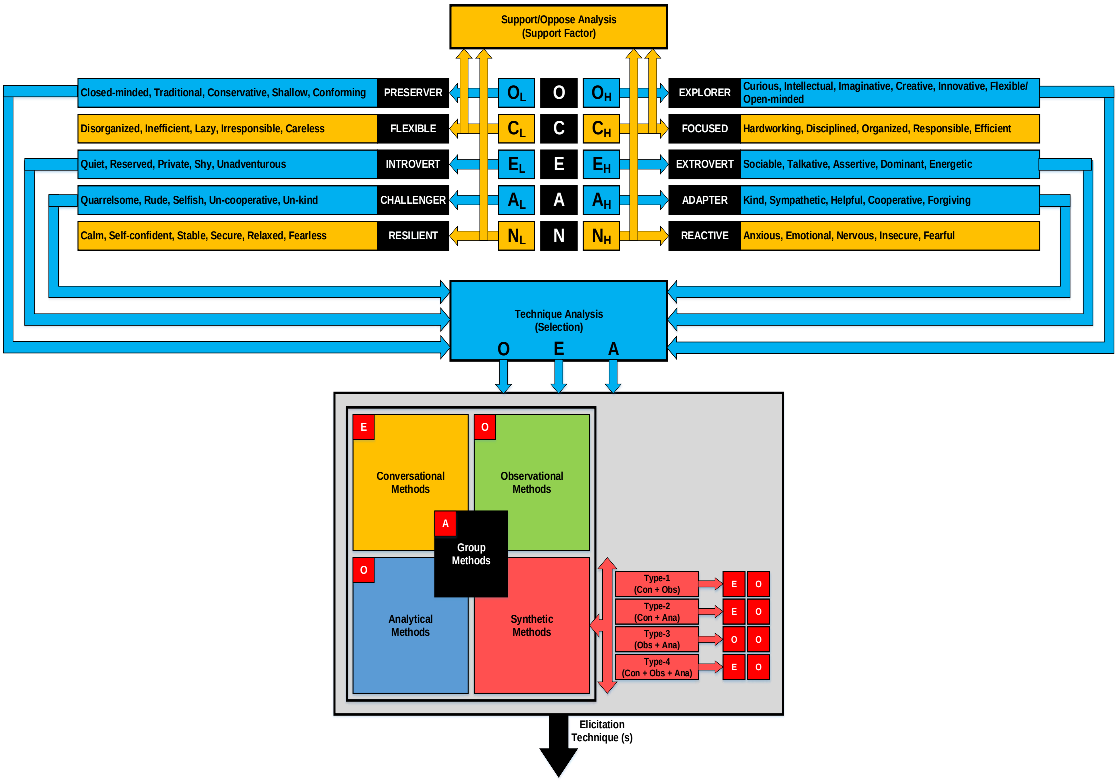


Figure-4.14 Techniques Mapping with Personality Traits

Initial Mapping Phase: The initial mapping phase maps big-five personality traits of conscientiousness and neuroticism to perform the support/oppose analysis to find out the support factors. During this initial mapping, the low and high facets of these two big-five traits are mapped systematically to find out support factors that will be used by the requirements elicitation technique selection process. The support/oppose factors guide the requirements engineering teams about the overall health of the elicitation process using selected requirements elicitation techniques. The overall health of the requirements elicitation process will be relatively best if the support/oppose factor is best. Similarly, the overall health of the requirements elicitation process will be relatively average if the support/oppose factor is average. Similarly, the overall health of the requirements elicitation process will be relatively worst if the support/oppose factor is worst.

Final Mapping Phase: The final mapping phase maps remaining three big-five traits of openness, extroversion and agreeableness to identify the related class/category of the elicitation techniques. If the extroversion trait of the user is high, then conversational techniques are selected for use during the requirements elicitation process. However, if the extroversion trait of the user is low, then conversational techniques are not selected for use during the requirements elicitation process. Similarly, if the openness trait of the user is high, then observational and analytical techniques are selected for use during the requirements elicitation process. However, if the openness trait of the user is low, then observational and analytical techniques are not selected for use during the requirements elicitation process. Similarly, if the agreeableness trait of the user is high, then group-based techniques are selected for use during the requirements elicitation process. However, if the agreeableness trait of the user is low, then group-based techniques are not selected for use during the requirements elicitation process.

4.8.4.4 Techniques Selection Process Structure

The main structure of the requirements elicitation techniques selection process of the proposed framework is design in a hierarchical form to decompose a complex computational problem into a set of simple computational tasks. There are different stages designed in the technique selection process of the proposed framework where each stage is responsible to perform a certain part of whole computation. There are three main stages of the requirements elicitation techniques selection process of the proposed framework including *Stage-1 (Feasibility Analysis), Stage-2 (Preference Analysis)* and *Stage-3 (Personality Analysis).* Consider the given figure-4.15, which shows the complete hierarchical design structure of the requirements elicitation technique selection process of the proposed framework.

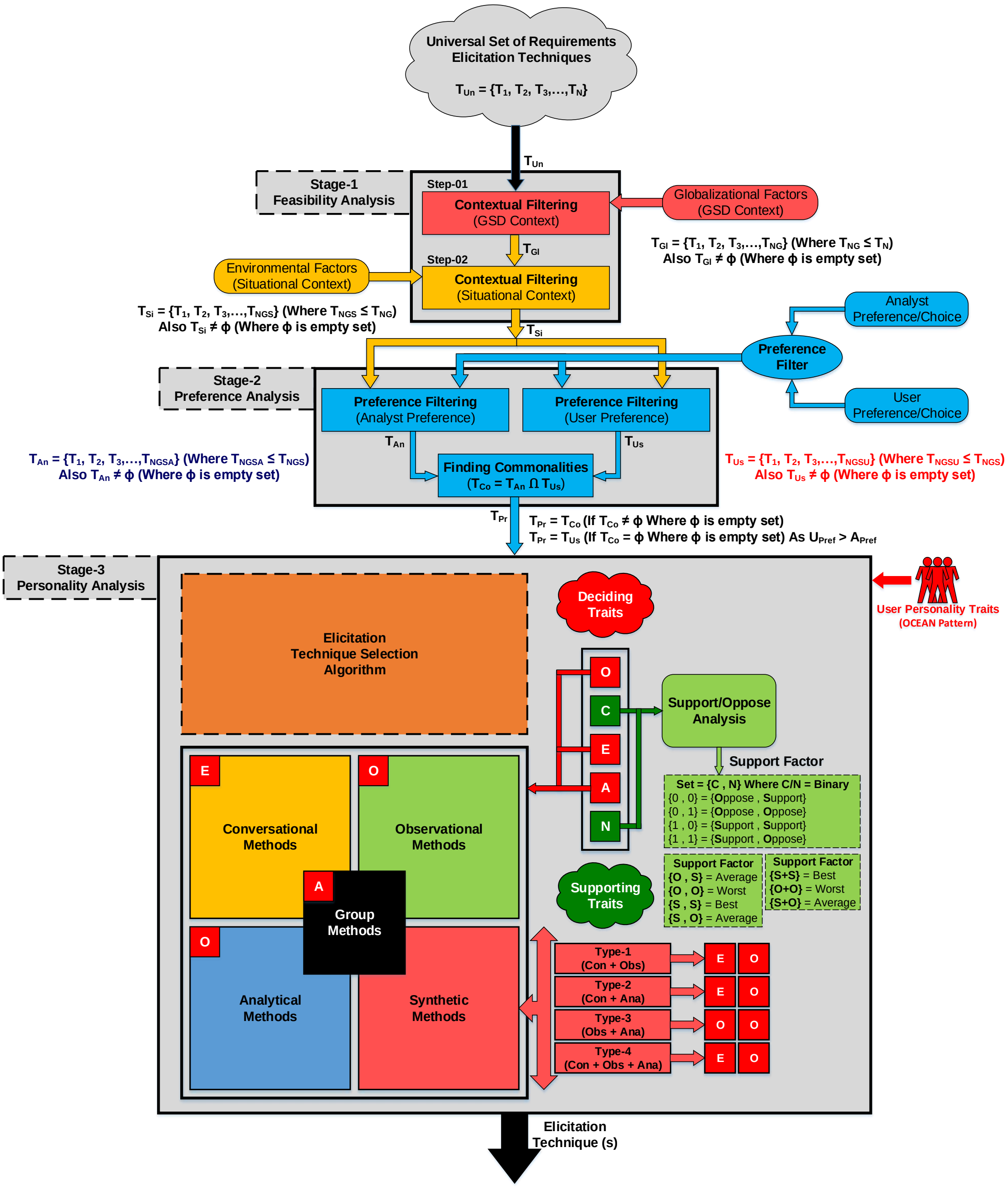


Figure-4.15 Structure of RE Technique Selection Process

- ***Stage-1 (Feasibility Analysis)***

The requirements elicitation techniques selection process of the proposed framework starts by taking the input at the feasibility analysis stage in form of a universal set of requirements elicitation techniques available in the domain. Let us assume that the input taken by the feasibility stage is universal set T_{Un}, Here $T_{Un} = \{T_1, T_2, T_3 \ldots T_N\}$, Where

T1, T2, T3 … T_N represent to different requirements elicitation techniques available in the domain of requirements engineering.

***Step-1 (Contextual Filtering for GSD Context)*:** Now the feasibility analysis stage executes the step-1 (contextual filtering for GSD context). During the contextual filtering step, the process analyzes the global software development context. In GSD context analysis, the process computes the globalization factors of global software development context for the anticipated project.

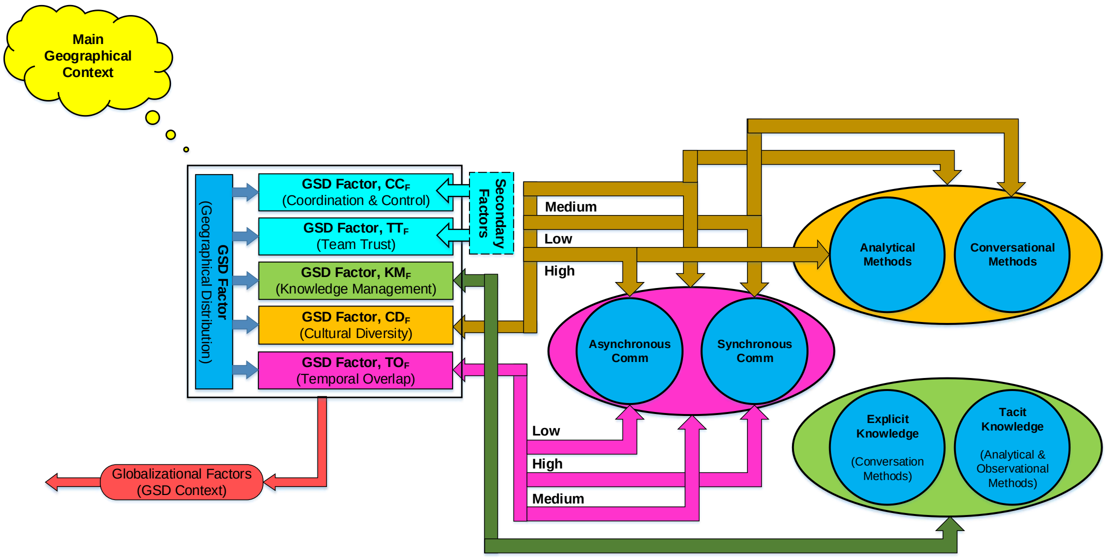


Figure-4.16 Globalization Factors Analysis

Globalization factors analysis computes the different global software development factors of the project including *Geographical Distribution (GD), Temporal Overlap Factor (TO_F), Cultural Diversity Factor (CD_F), Knowledge Management Factor (KM_F), Team Trust Factor (TT_F) and Coordination and Control Factor (CC_F).* Consider the given figure-4.16, which shows the details of the globalization factors analysis performed to compute their values for project. The geographical distribution is considered as the main geographical context of the project on which the remaining factors depend. The team trust factor, coordination and control factor are considered as secondary factors for the analysis. If the temporal overlap is low, asynchronous communication is recommended. However, if the temporal overlap is high, synchronous communication is recommended. If the temporal overlap is medium, mixed communication is recommended. If the cultural diversity is low, synchronous communication and conversational elicitation techniques are recommended. However, if the cultural diversity is high, asynchronous communication and analytical elicitation techniques are recommended. If the cultural diversity is medium, then mixed communication and mixed elicitation techniques are recommended. After the completion of the contextual filtering, the universal set T_{Un} of elicitation techniques is transformed/converted to T_{Gl}, where T_{Gl} is represented as:

$$\mathbf{T_{Gl} = \{T_1, T_2, T_3, \ldots, T_{NG}\} \ (Where\ T_{NG} \leq T_N)}$$
$$\mathbf{Also,\ T_{Gl} \neq \phi \ (Where\ \phi\ is\ empty\ set)}$$

***Step-2 (Contextual Filtering for Situational Context)*:** The T_{Gl} becomes the input for step-2 where the contextual filtering is performed for situational context of the project. This step considers the environmental factors of the project, which define the situational context of the project. The environmental factors of the project include *Organization Factors* (OR_F), *Stakeholder Factors* (ST_F), *Project Factors* (PJ_F), *Process Factor* (PO_F) and *Product Factors* (PD_F). Consider the given figure-4.17, which shows the complete details of all these environmental factors and their different attributes.

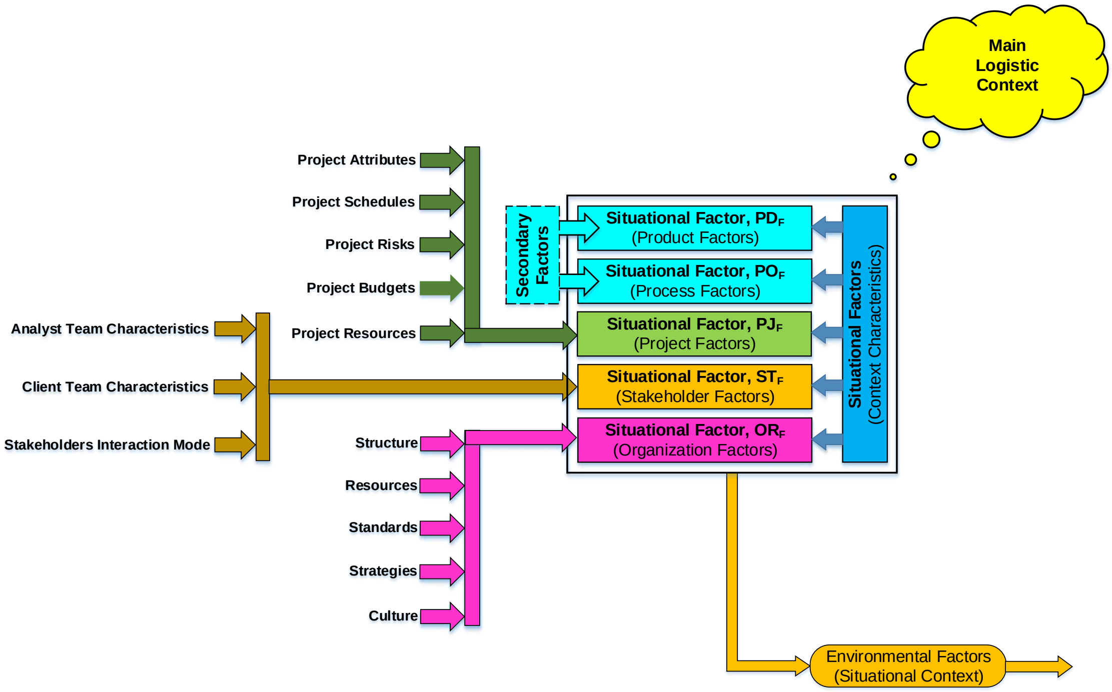


Figure-4.17 Environmental Factors Analysis

The organizational factors of the project include organization structure, organization resources, organization standards, organization strategies and organization culture. The stakeholder's factors include analyst team characteristics, client team characteristics and stakeholder's interaction modes. The project factors include project resources, project budget, project risks, project schedules and project attributes. The situational factors are considered as the main logistic context. The process factors and product factors are considered as the secondary factors during the situational factor analysis process. After the completion of the situational context analysis, the elicitation techniques set T_{GI} is transformed/reduced into the T_{Si} , where T_{Si} is represented as:

$$\mathbf{T_{Si} = \{T_1, T_2, T_3, \ldots, T_{NGS}\}\ (Where\ T_{NGS} \leq T_{NG})}$$

$$\mathbf{Also,\ T_{Si} \neq \phi\ (Where\ \phi\ is\ empty\ set)}$$

- ***Stage-2 (Preference Analysis)***

The preference analysis stage of the requirements elicitation technique selection process considers the user preferences/choices and analyst preferences/choices to further short list the available elicitation techniques set. This stage performs three computations including analyst preference filtering, user preference filtering and finding commonalities. The analyst preference filtering transforms/converts the elicitation techniques set T_{Si} into T_{An} where T_{An} is represented as:

$$\mathbf{T_{An} = \{T_1, T_2, T_3,\ldots,T_{NGSA}\}\ (Where\ T_{NGSA} \leq T_{NGS})}$$
$$\mathbf{Also,\ T_{An} \neq \phi\ (Where\ \phi\ is\ empty\ set)}$$

Similarly, the user preference filtering transforms/converts the elicitation techniques set T_{Si} into T_{Us} where T_{Us} is represented as:

$$\mathbf{T_{Us} = \{T_1, T_2, T_3,\ldots,T_{NGSU}\}\ (Where\ T_{NGSU} \leq T_{NGS})}$$
$$\mathbf{Also,\ T_{Us} \neq \phi\ (Where\ \phi\ is\ empty\ set)}$$

At the end, the finding commonalities process is executed to find out any set of elicitation techniques common to both user choices and analyst choices. After doing so the elicitation techniques set T_{Si} is transformed/converted into T_{Pr} where T_{Pr} is represented as:

$$\mathbf{T_{Pr} = T_{Us}\ (If\ T_{Co} = \phi\ Where\ \phi\ is\ empty\ set)\ As\ U_{Pref} > A_{Pref}}$$
$$\mathbf{T_{Pr} = T_{Co}\ (If\ T_{Co} \neq \phi\ Where\ \phi\ is\ empty\ set)}$$

- ***Stage-3 (Personality Analysis)***

The personality analysis stage of the requirements elicitation techniques selection process of the proposed framework receives the elicitation techniques set T_{Pr} and user personality traits (OCEAN pattern) as inputs and runs its internal algorithm to select the most suitable requirements elicitation technique. The user personality traits are received as OCEAN (openness, conscientiousness, extroversion, agreeableness and neuroticism) pattern. The values of "C" and "N" are taken as supporting traits which are used to compute support/oppose factor using support/oppose analysis. Consider the figure-4.18, which shows the method of the support/oppose analysis and support/oppose factor. The support/oppose factor can have the values of best, worst and average. The support/oppose factor shows the overall health of the requirements elicitation process with selected requirements elicitation techniques.

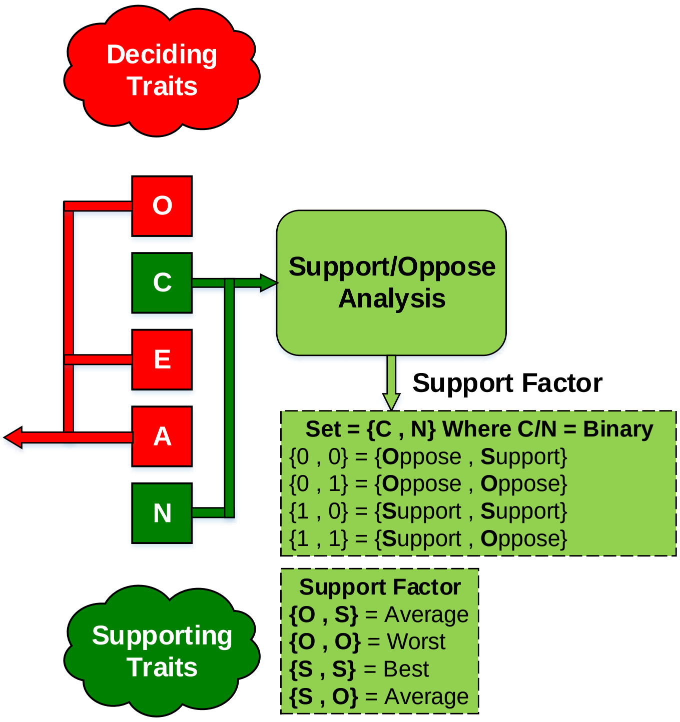


Figure-4.18 Support/Oppose Analysis

The values of "O", "E" and "A" are taken as deciding traits, which are used to select the most suitable elicitation techniques according to user personality traits. If the value of the trait "O" is high, then observational or analytical elicitation techniques are selected. However, if the value of the trait "O" is low, then observational or analytical elicitation techniques are not selected. If the value of the trait "E" is high, then conversational elicitation techniques are selected. However, if the value of the trait "E" is low, then conversational elicitation techniques are not selected. If the value of the trait "A" is high, then group-based elicitation techniques are selected. However, if the value of the trait "A" is low, then group-based elicitation techniques are not selected. Similarly, the selection for synthetic elicitation techniques can be made using the values of "E", "O". Consider the given figure-4.19, which shows the complete process of the personality analysis for selecting the elicitation techniques using users deciding personality traits.

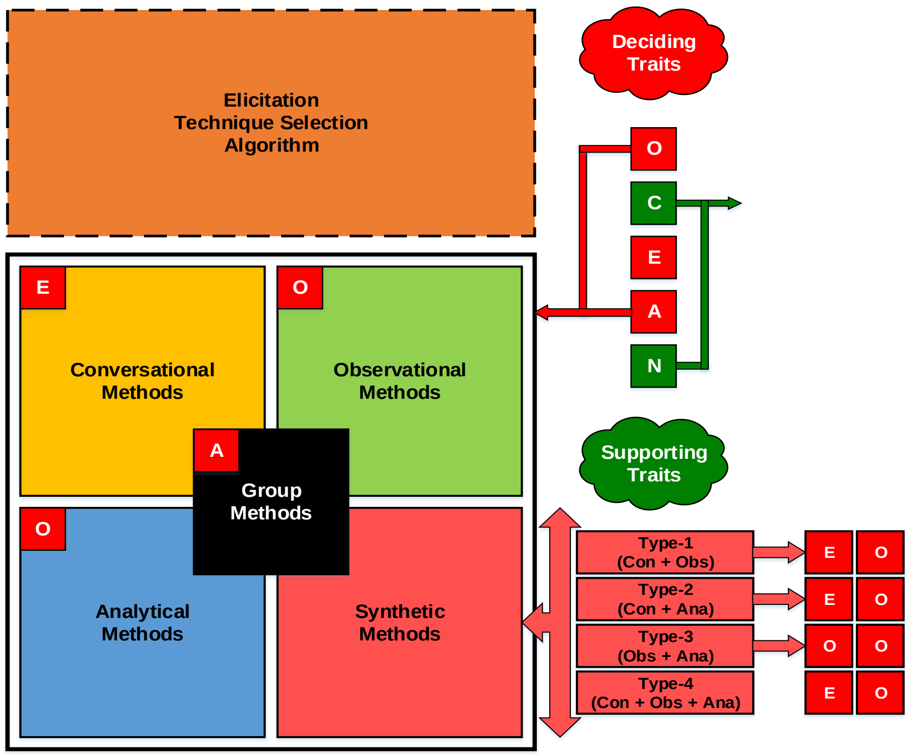


Figure-4.19 Personality Traits Analysis for RE Techniques Selection Process

There is an elicitation technique selection algorithm, which is used during the personality traits analysis stage of the process. The elicitation technique selection algorithm used during personality traits analysis is given below:

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Elicitation Technique Selection Algorithm

Assumption-1: Global-Context (GSD) is considered as the main context/scenario, which defines the geological constraints for elicitation process. Hence, GSD context has primary priority.

Assumption-2: Situational-Context is considered as the sub-context/scenario, which defines the logistic constraints for elicitation process. The situational context lies inside the GSD context and has the secondary priority.

Assumption-3: User-Preference has the high priority as compared to Analyst-Preference because it is a user-centric framework.

Assumption-4: User-Personality has the high priority as compared to User-Preference because personality better guides about technique suitability as compared to User-Preference.

Let T_{Pr} is a set of techniques left after applying Contextual Filtering (CF) and Preference Filtering (PF), Where $T_{Pr} \neq \phi$ (Where ϕ is an empty set),

Also, $T_{Pr} = (T_{Co} \text{ or } T_{Us}) \leq T_{Si} \leq T_{Gl} \leq T_{Un}$

Phase-1 (Techniques Classification Phase)

Step-1 (Techniques Super-Classification): Classify T_{Pr} into following four main categories/groups:

Type-1: Conversational Methods (Con)

Type-2: Observational Methods (Obs)

Type-3: Analytical Methods (Ana)

Type-4: Synthetic Methods (Syn)

Step-2 (Group-Based Sub-Classification): Sub-classify Con, Obs, Ana, Syn methods into following two sub-categories/sub-groups:

Type-1: Group Based Methods

Type-2: Non-Group Based Methods

Step-3 (Synthetic Methods Sub-Classification): Sub-classify Synthetic Methods (Syn) into following four sub-categories/sub-groups:

Type-1: Combination of (Con + Obs)

Type-2: Combination of (Con + Ana)

Type-3: Combination of (Obs + Ana)

Type-4: Combination of (Con + Obs + Ana)

Phase-2 (Personality Traits Mapping Phase)

Step-4 (Map Supporting-Traits to Calculate Support Factor): Check Value of Trait 'C' and Trait 'N' of OCEAN Pattern of Elicit/User Personality.

Iteration-1: Assign Supporting/Opposing Attribute to Trait 'C' and Trait 'N'

If C = High: Trait is Supporting & If C = Low: Trait is Opposing

If N = Low: Trait is Supporting & If N = High: Trait is Opposing

Iteration-2: Find Cumulative Effect of Supporting/Opposing Attribute to find the net Support Factor (SF):

Set = {C , N} Where C/N = Binary

{0 , 0} = {**O**ppose , **S**upport}

{0 , 1} = {**O**ppose , **O**ppose}

{1 , 0} = {**S**upport , **S**upport}

{1 , 1} = {**S**upport , **O**ppose}

Support Factor (SF)

{O , S} = Average (SF-3)

{O , O} = Worst (SF-2)

{S , S} = Best (SF-1)

{S , O} = Average (SF-3)

Iteration-3: Classify Support Factors into following three major categories/groups:

Support Factor SF-1 = Best = {S, S}

Support Factor SF-2 = Worst = {O, O}

Support Factor SF-3 = Average = {(O, S), (S, O)} = {O, S}

Step-5 (Map Deciding-Traits to Categorize Techniques): Check Value of Trait 'E', Trait 'O' and Trait 'A' of OCEAN Pattern of Elicit/User Personality.

If E = High: Select Conversational Methods

Else Select Non-Conversational Methods

If O = High: Select Analytical and/or Observational Methods

Else Select Non-Analytical and/or Non-Observational Methods

If A = High: Select Group-Based Methods

Else Select Non-Group-Based Methods

Phase-3 (Suitable Technique Selection Phase)

Step-6 (Select Suitable Elicitation Techniques): Select the most suitable elicitation technique by considering the values of Trait 'E', Trait 'O' and Trait 'A' of OCEAN Pattern of Elicit/User Personality.

{(E, O) A} = Selected Techniques

{(L, L), L} = **None** (Exception)

{(L, L), H} = **None** (Exception)

{(L, H), L} = Non-Group {**Ana** and/or **Obs** and/or **Syn** (Type-3)}

{(L, H), H} = Group {**Ana** and/or **Obs** and/or **Syn** (Type-3)}

{(H, L), L} = Non-Group (**Con**)

{(H, L), H} = Group (**Con**)

{(H, H), L} = Non-Group {**Con** and/or **Ana** and/or **Obs** and/or **Syn** (Type-1 and/or Type-2 and/or Type-4)}

{(H, H), H} = Group {**Con** and/or **Ana** and/or **Obs** and/or **Syn** (Type-1 and/or Type-2 and/or Type-4)}

Step-7 (Calculate Net-Effectiveness of Selected Elicitation Techniques): Assign Support Factor (SF) with Selected Elicitation Technique to Assess Technique Net-Effectiveness.

Technique Net-Effectiveness (TNE) = Selected Technique (ST) + Support Factor (SF)

Best Scenario (Best TNE) = ST + SF-1

Worst Scenario (Worst TNE) = ST + SF-2

Average Scenario (Average TNE) = ST + SF-3

****

4.8.5 Groupware Tools Selection Process

The requirements elicitation groupware tools selection process initially performs the groupware tools classifications and then performs the elicitation groupware tools selection depending upon the environmental factors and globalization factors of the project. Some other external project attributes may affect the process of requirements elicitation groupware tools selection. The requirements elicitation groupware tools selection process of the proposed framework also considers all these external factors during the selection process. Therefore, the requirements elicitation groupware tools selection process is divided into four main phases including RE groupware tools classification, RE groupware tools factors analysis, RE groupware tools mapping with personality traits and RE groupware tools selection process structure.

4.8.5.1 Groupware Tools Classification

The groupware tools can be classified by considering the groupware time/space chart (Ignat, 2018) which classifies the groupware technologies according to four parameters of *Same Place (Co-Located)* vs *Different Place (Remote Located)* and *Same Time (Synchronous)* vs *Different Time (Asynchronous)*. Consider the given figure-4.20, which shows the classification of groupware technology based on these four parameters (Ignat, 2018). The figure also shows exemplary list of each category of groupware technologies according to these four parameters of classifications. The scope of the proposed requirements elicitation framework is limited to only geographically distributed context including different places using synchronous or asynchronous groupware technologies. Accordingly, the requirements elicitation groupware tools can be categorized into two major types including asynchronous communication tools and synchronous communication tools depending upon their communication mode/type.

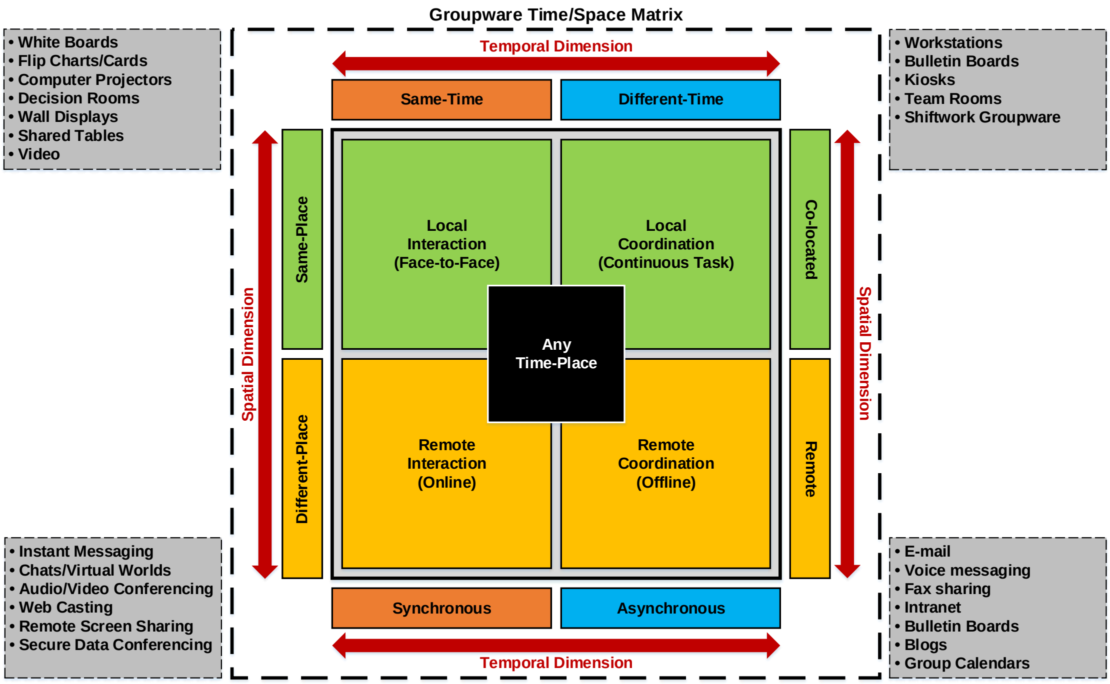


Figure-4.20 Groupware Time/Space Matrix

The ***Asynchronous Communication Tools*** are offline communication tools in which both sender and receivers are not required to remain active at the same time on internet.

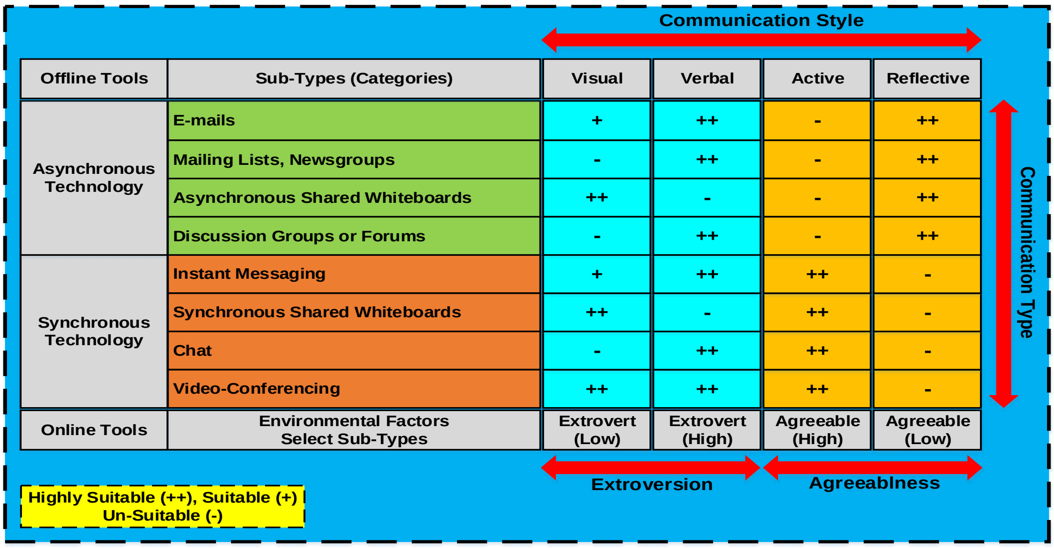
The sender and receivers can send and receive their messages when they connect on internet and become online. The asynchronous communication tools may include emails, mailing lists, news groups, and asynchronous shared whiteboards and discussion forums. The participants of asynchronous conversations can send messages at any time while the receivers can receive these messages at any time when then become online. The asynchronous communication is based on individual communication with other people. The ***Synchronous Communication Tools*** on the other hand are active tools in which sender and receivers both are required to become online at the same time to communicate with each other. The synchronous communication tools give the illusion of face-to-face conversations. The synchronous communication can be used to perform group-based communication. The synchronous communication tools may include instant messaging, synchronous shared whiteboards, chats and videoconferencing.

The groupware tools can also be classified by using communication and interaction styles proposed by Felder-Silverman model. The ***Felder-Silverman (F-S) Model*** can also be used to classify the groupware communication tools according to the different types of interaction styles and information sharing (Pekić, Jovanovski, & Pekić, 2016). The Felder-Silverman (F-S) model categories the people into following four major types depending upon their way of interactions and learning styles including either they are sensing or intuitive, visual or verbal, active or reflective, sequential or global (Wang & Mendori, 2015):

- ***1A_Sensing*** (Practical, Concrete, Oriented Toward Facts and Procedures)
- ***1B_Intuitive*** (Innovative, Conceptual, Oriented Toward Theories and Meanings)
- ***2A_Visual*** (Visual Representations Oriented –Diagrams, Pictures, Flow Charts)

- ***2B_Verbal*** (Spoken and Written Explanations of Artifacts)
- ***3A_Active*** (Working with Others, Working by Trying Things Out)
- ***3B_Reflective*** (Working Alone, Thinking Things Through)
- ***4A_Sequential*** (Learn in Small Leaps/Steps, Linear, Orderly)
- ***4B_Global*** (Learn in Large Leaps/Steps, Holistic, Systems Thinkers)

The sequential vs. global attributes are concerned with the how people work in daily life. The sequential people work serially on single task at a time while global people work in parallel on multiple tasks at the same time. There is no role of sensing/intuitive and sequential/global attributes in classification of requirements elicitation groupware tools. Hence, the visual/verbal and active/reflective attributes of the Felder-Silverman (F-S) model are used by researchers to classify the available groupware tools. Consider the given figure-4.21, which shows the classification of groupware tools based on synchronous/asynchronous communication tools, visual/verbal communication tools and active/reflective communication tools.



Offline Tools	Sub-Types (Categories)	Visual	Verbal	Active	Reflective
Asynchronous Technology	E-mails	+	++	-	++
	Mailing Lists, Newsgroups	-	++	-	++
	Asynchronous Shared Whiteboards	++	-	-	++
	Discussion Groups or Forums	-	++	-	++
Synchronous Technology	Instant Messaging	+	++	++	-
	Synchronous Shared Whiteboards	++	-	++	-
	Chat	-	++	++	-
	Video-Conferencing	++	++	++	-
Online Tools	Environmental Factors Select Sub-Types	Extrovert (Low)	Extrovert (High)	Agreeable (High)	Agreeable (Low)

Figure-4.21 Groupware Tools Classification

4.8.5.2 Groupware Tools Factors Analysis

The requirements elicitation groupware tools selection process initially defines a set of external factors that may affect the requirements elicitation groupware tools selection process. In case of requirements elicitation process executing in global software development projects, the requirements elicitation groupware tools selection process depends on a diverse set of environmental and globalization factors. The requirements elicitation groupware tools selection process depends on eight factors. These classes of factors include selected requirements elicitation technique, problem-domain factors, solution-domain factors, project-domain factors, user/developer team's factors, global software development domain factors, requirements engineering domain factors and psychology domain factors. Consider the given figure-4.22, which displays all these factors as a circular chart by grouping each of these factors according to their nature.

The problem-domain factors include the problem-domain characteristics (problem attributes/features). The solution-domain factors include the solution-domain characteristics (domain attributes/features). The project-domain factors include the requirements status (known requirements), the sources of requirements (information sources), the project status/situation (project context) and the project attributes (project facets). The user/developer team's factors include the stakeholder's characteristics (user, client, developers etc.), the analyst preferences (analyst choices) and the user preferences (user choices). The global software development domain factors include the temporal factors, the cultural factors and the linguistic factors. The requirements engineering domain factors include the elicitation techniques set (types and characteristics). The psychology domain factors include the user personality traits (big-five traits).

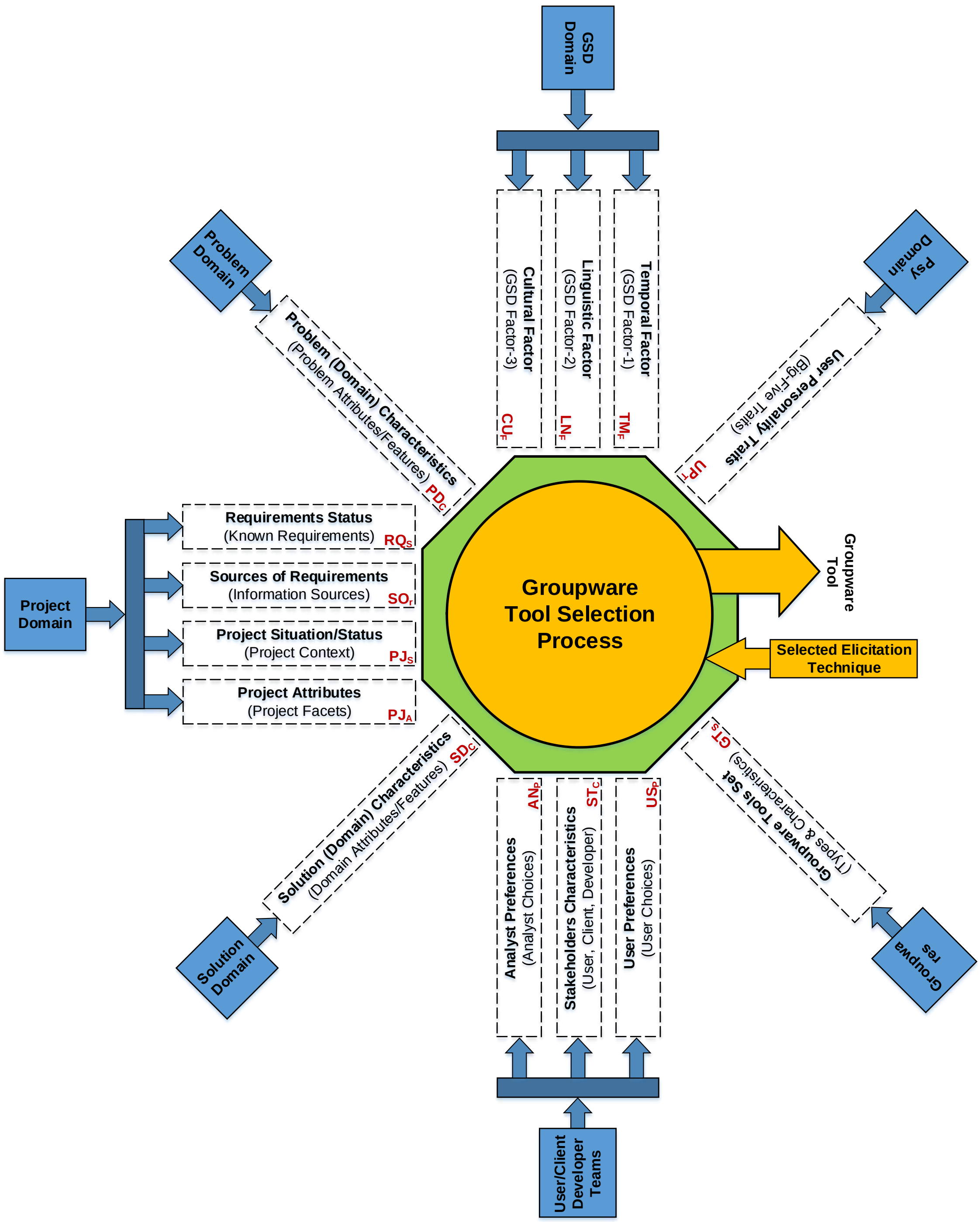


Figure-4.22 Factors for RE Groupware Tools Selection Process

4.8.5.3 Groupware Tools Mapping with Personality Traits

The big-five personality traits of the users are systematically mapped on the different categories of the requirements elicitation groupware tools. The requirements elicitation groupware tools are classified into two major categories including asynchronous and synchronous communication tools. The selection between asynchronous and synchronous communication tools is also dependent on temporal diversity, cultural diversity and linguistic diversity as is explained already. These two categories of groupware tools are further divided into two main types including visual vs verbal communication tools and active vs. reflective communication tools. In the first stage of mapping, the big-five personality traits of the users are mapped to select asynchronous or synchronous groupware tools. In the second stage of mapping, the big-five personality traits of users are mapped on other two types (visual/verbal and active/reflective). Consider the given figure-4.23, which shows the complete process of requirements elicitation groupware tools mapping with big-five personality traits.

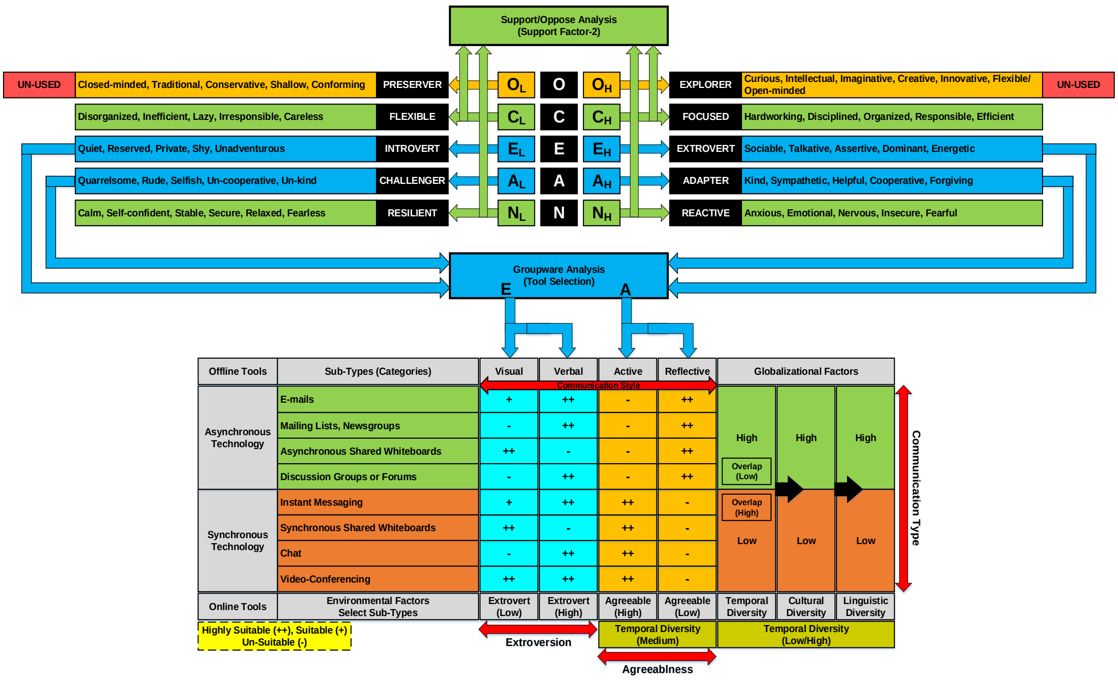


Figure-4.23 Groupware Tools Mapping with Personality Traits

Initial Mapping Phase: The initial mapping phase maps big-five personality traits of conscientiousness and neuroticism to perform the support/oppose analysis to find out the support factors. During this initial mapping, the low and high facets of these two big-five traits are mapped systematically to find out support factors that will be used by the requirements elicitation groupware tools selection process. The support/oppose factors guide the requirements engineering teams about the overall health of the elicitation process using selected requirements elicitation groupware tools. The overall health of the requirements elicitation process will be relatively best if the support/oppose factor is best. Similarly, the overall health of the requirements elicitation process will be relatively average if the support/oppose factor is average. Similarly, the overall health of the requirements elicitation process will be relatively worst if the support/oppose factor is worst.

Final Mapping Phase: The final mapping phase maps remaining three big-five traits of openness, extroversion and agreeableness to identify the related class/category of the elicitation groupware tools. The openness trait of the user personality is not used during this mapping because openness trait is neither concerned with asynchronous vs synchronous communication modes nor it is concerned other communication styles based on Felder-Silverman model. Hence, the openness trait is even not concerned with the classification of tools as visual/verbal communication tools and active/reflective communication tools. Therefore, the personality traits mapping on communication tools is only based on two traits of extroversion and agreeableness. If the extroversion trait of the user is high, then verbal communication tools/methods are selected for use during the requirements elicitation process. However, if the extroversion trait of the user is low, then visual communication tools/methods are selected for use during the requirements elicitation process. Similarly, if the agreeableness trait of the user is high, then active communication tools/methods are selected for use during the requirements elicitation process. However, if the agreeableness trait of the user is low, then reflective communication tools/methods are selected for use during the requirements elicitation process.

4.8.5.4 Groupware Tools Selection Process Structure

The overall structure of the requirements elicitation groupware tools selection process of the proposed framework is design in a hierarchical form to decompose a complex computational problem into a set of simple computational tasks. There are different stages designed in the technique selection process of the proposed framework where each stage is responsible to perform a certain part of whole computation. There are three main stages of the requirements elicitation groupware tools selection process of the proposed framework including *Stage-1 (Feasibility Analysis), Stage-2 (Preference Analysis)* and *Stage-3 (Personality Analysis).* Consider the given figure-4.24, which shows the complete hierarchical design structure of the requirements elicitation groupware tools selection process of the proposed framework.

- ***Stage-1 (Feasibility Analysis)***

The requirements elicitation groupware tools selection process of the proposed framework starts by taking the input at the feasibility analysis stage in form of a universal set of requirements elicitation groupware tools available in the domain. Let us assume that the input taken by the feasibility stage is universal set G_{Un}, Here $G_{Un} = \{G_1, G_2, G_3 \dots G_N\}$, Where G1, G2, G3 … G_N represent to different requirements elicitation groupware tools available in the domain of requirements engineering.

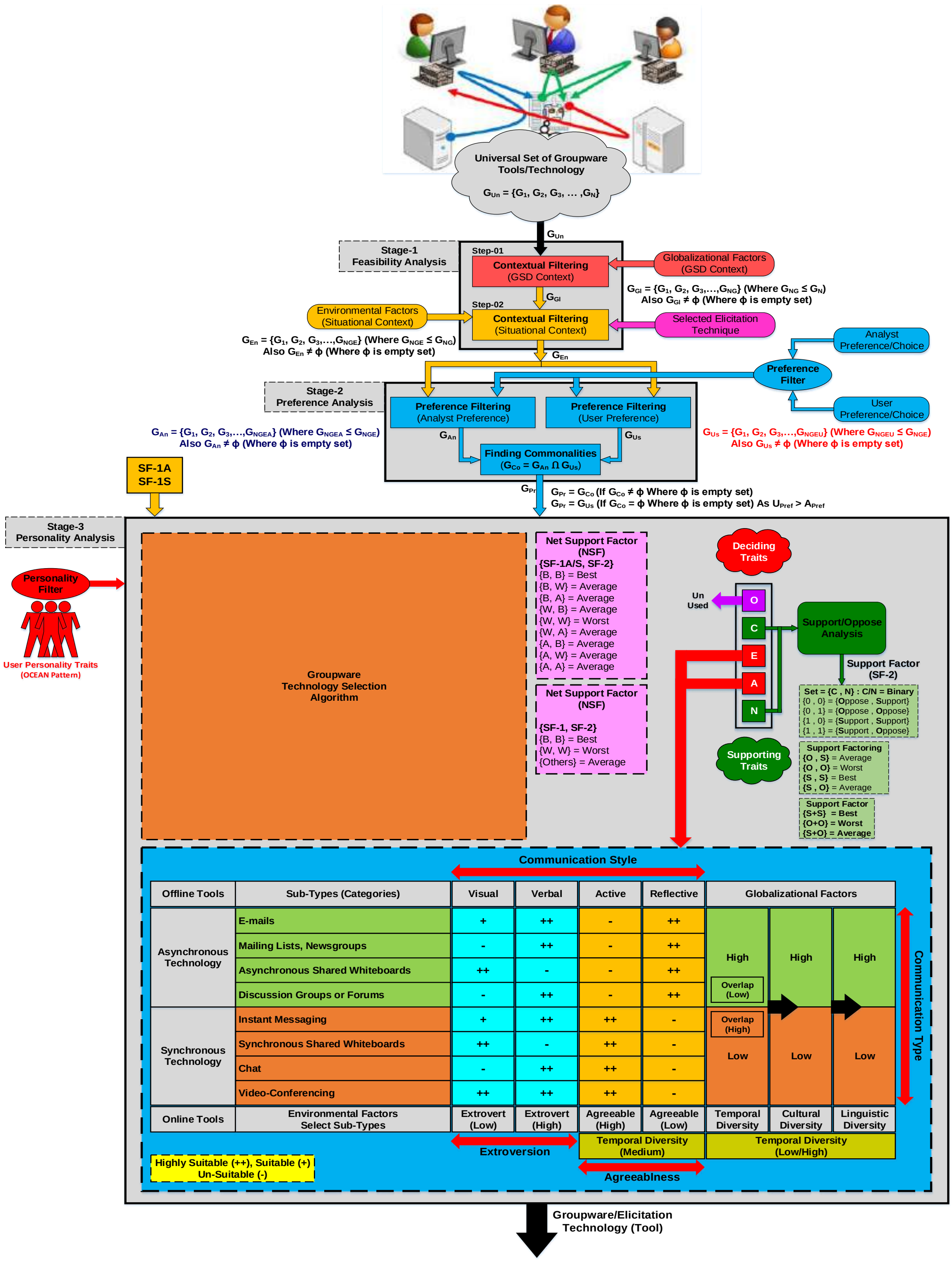


Figure-4.24 Structure of RE Groupware Tools Selection Process

Step-1 (Contextual Filtering for GSD Context): Now the feasibility analysis stage executes the step-1 (contextual filtering for GSD context). During the contextual filtering step, the process analyzes the global software development context. In GSD context analysis, the process computes the globalization factors of global software development context of the project. Globalization factors analysis computes the different global software development factors of the project including *Geographical Distribution (GD), Temporal Overlap Factor (TO_F), Cultural Diversity Factor (CD_F), Knowledge Management Factor (KM_F), Team Trust Factor (TT_F)* and *Coordination and Control Factor (CC_F).* Consider the given figure-4.25, which shows the details of the globalization factors analysis performed to compute their values for project.

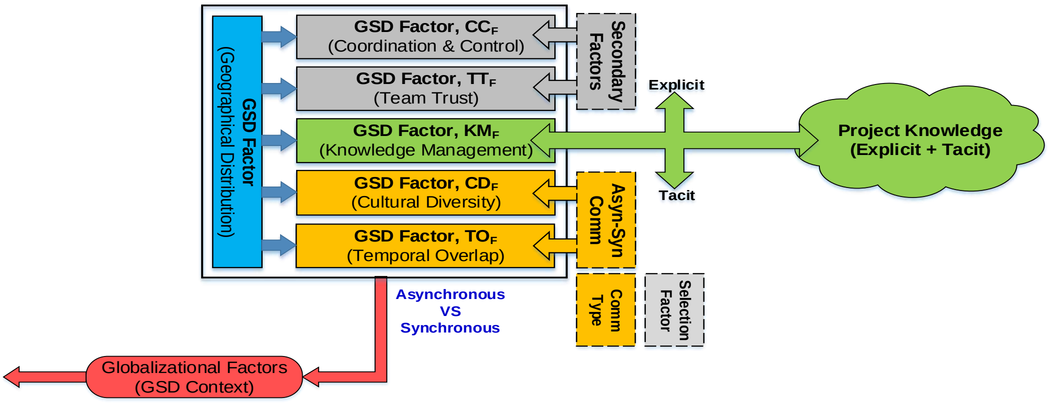


Figure-4.25 Globalization Factors Analysis

The geographical distribution is considered as the main geographical context of the project on which the remaining factors depend. The team trust factor, coordination and control factor are considered as secondary factors for the analysis. If the temporal overlap is low, asynchronous communication tools are recommended. However, if the temporal overlap is high, synchronous communication tools are recommended. Similarly, if the temporal overlap is medium, the mixed communication tools are recommended. If the cultural diversity is low, synchronous communication tools are recommended. However, if the cultural diversity is high, asynchronous communication tools are recommended. Similarly, if the cultural diversity is medium, then mixed communication tools are recommended. After the completion of the contextual filtering, the universal set G_{Un} of elicitation groupware tools is transformed/converted to G_{Gl}, where G_{Gl} is represented as:

$$\mathbf{G_{Gl} = \{G_1, G_2, G_3,\ldots,G_{NG}\}\ (Where\ G_{NG} \leq G_N)}$$
$$\mathbf{Also,\ G_{Gl} \neq \phi\ (Where\ \phi\ is\ empty\ set)}$$

***Step-2 (Contextual Filtering for Situational Context)*:** The G_{Gl} becomes the input for step-2 where the contextual filtering is performed for situational context of the project. The selected requirements elicitation technique also become the input for this step. This step considers the environmental factors of the project and selected requirements elicitation technique, which define the situational context of the project. The environmental factors of the project include *Organization Factors (OR_F), Stakeholder Factors (ST_F), Project Factors (PJ_F), Process Factor (PO_F)* and *Product Factors (PD_F).* Consider the given figure-4.26, which shows the complete details of all these environmental factors and their different attributes.

The organizational factors and stakeholder's factors are used to make decision about either use asynchronous tools or synchronous tools. The organizational factors of the project include organization structure, organization resources, organization standards, organization strategies and organization culture. The stakeholder's factors include analyst team characteristics, client team characteristics and stakeholder's interaction modes. The project factors include project resources, project budget, project risks, project schedules and project attributes. The situational factors are considered as the main logistic context. The process factors and product factors are considered as the secondary factors during the situational factor analysis process.

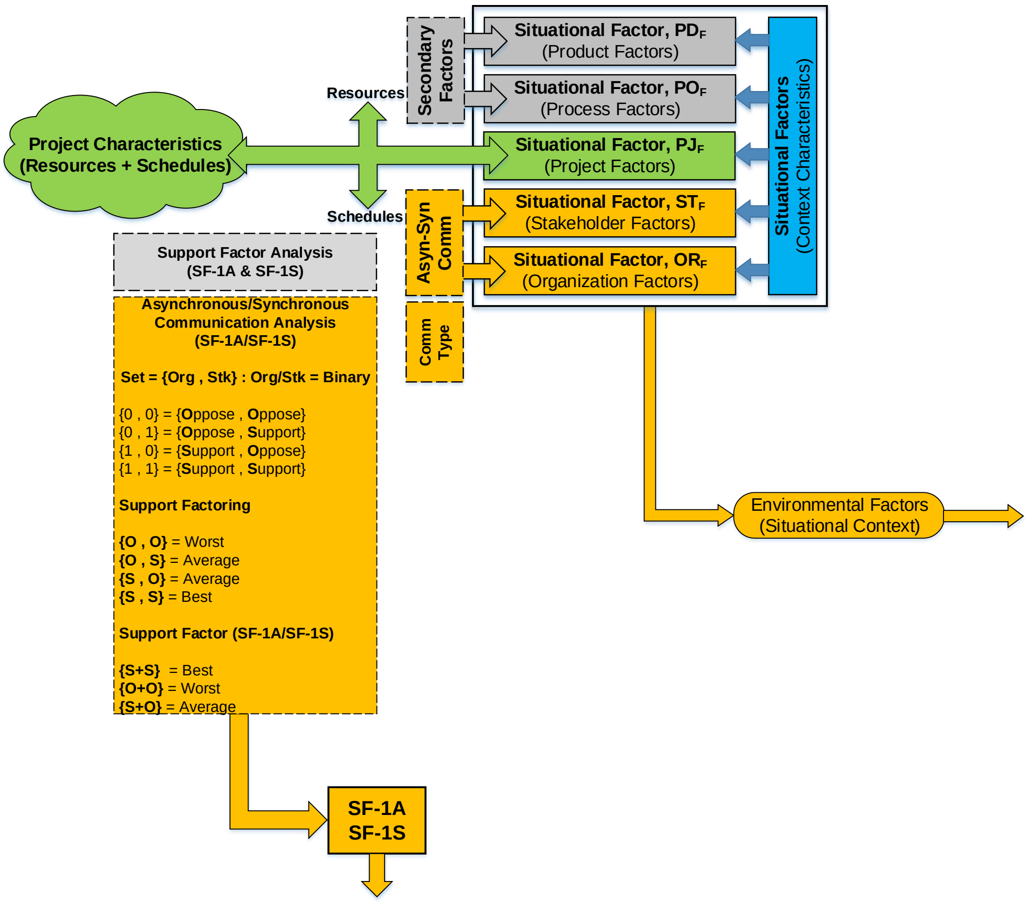


Figure-4.26 Environmental Factors Analysis

The environmental factors are also used to compute support factors for asynchronous context and synchronous context. After the completion of the situational context analysis, the elicitation groupware tools set G_{Gl} is transformed/reduced into the G_{En} , where G_{En} is represented as:

$$\mathbf{G_{En} = \{G_1, G_2, G_3,, G_{NGE}\} \text{ (Where } G_{NGE} \leq G_{NG})}$$
$$\mathbf{\text{Also, } G_{En} \neq \phi \text{ (Where } \phi \text{ is empty set)}}$$

- ***Stage-2 (Preference Analysis)***

The preference analysis stage of the requirements elicitation groupware tools selection process considers the user preferences/choices and analyst preferences/choices to further shortlist the available elicitation groupware tools set. This stage performs three computations including analyst preference filtering, user preference filtering and finding commonalities. The analyst preference filtering transforms/converts the elicitation groupware tools set G_{En} into G_{An} where G_{An} is represented as:

$$\mathbf{G_{An} = \{G_1, G_2, G_3, \ldots, G_{NGEA}\} \text{ (Where } G_{NGEA} \leq G_{NGE})}$$
$$\mathbf{\text{Also, } G_{An} \neq \phi \text{ (Where } \phi \text{ is empty set)}}$$

Similarly, the user preference filtering transforms/converts the elicitation groupware tools set G_{En} into G_{Us} where G_{Us} is represented as:

$$\mathbf{G_{Us} = \{G_1, G_2, G_3, \ldots, G_{NGEU}\} \text{ (Where } G_{NGEU} \leq G_{NGE})}$$
$$\mathbf{\text{Also, } G_{Us} \neq \phi \text{ (Where } \phi \text{ is empty set)}}$$

At the end, the finding commonalities process is executed to find out any set of elicitation groupware tools common to both user choices and analyst choices. After doing so the elicitation groupware tools set is transformed/converted into G_{Pr} where G_{Pr} is represented as:

$$\mathbf{G_{Pr} = G_{Us} \text{ (If } G_{Co} = \phi \text{ Where } \phi \text{ is empty set) As } U_{Pref} > A_{Pref}}$$
$$\mathbf{G_{Pr} = G_{Co} \text{ (If } G_{Co} \neq \phi \text{ Where } \phi \text{ is empty set)}}$$

- ***Stage-3 (Personality Analysis)***

The personality analysis stage of the requirements elicitation groupware tools selection process of the proposed framework receives the support factors (SF-1A and SF-1S), elicitation groupware tools set G_{Pr} and user personality traits (OCEAN pattern) as inputs and runs its internal algorithm to select the most suitable requirements elicitation groupware tools. The user personality traits are received as OCEAN (openness, conscientiousness, extroversion, agreeableness and neuroticism) pattern. The values of "C" and "N" are taken as supporting traits which are used to compute support/oppose factor (SF-2) using support/oppose analysis. The support/oppose analysis factors SF-1 and SF-2 are then used to calculate the net support factor (NSF). The support/oppose factor can have the values of best, worst and average. The support/oppose factor shows the overall health of the requirements elicitation process with selected requirements elicitation groupware tools. Consider the figure-4.27, which shows the method of the support/oppose analysis and support/oppose factor.

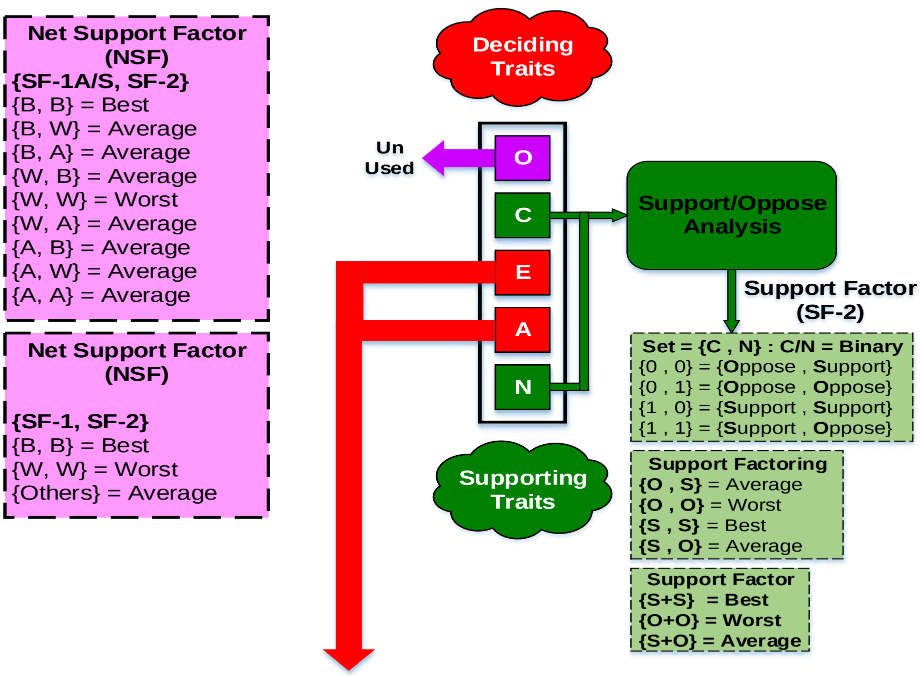
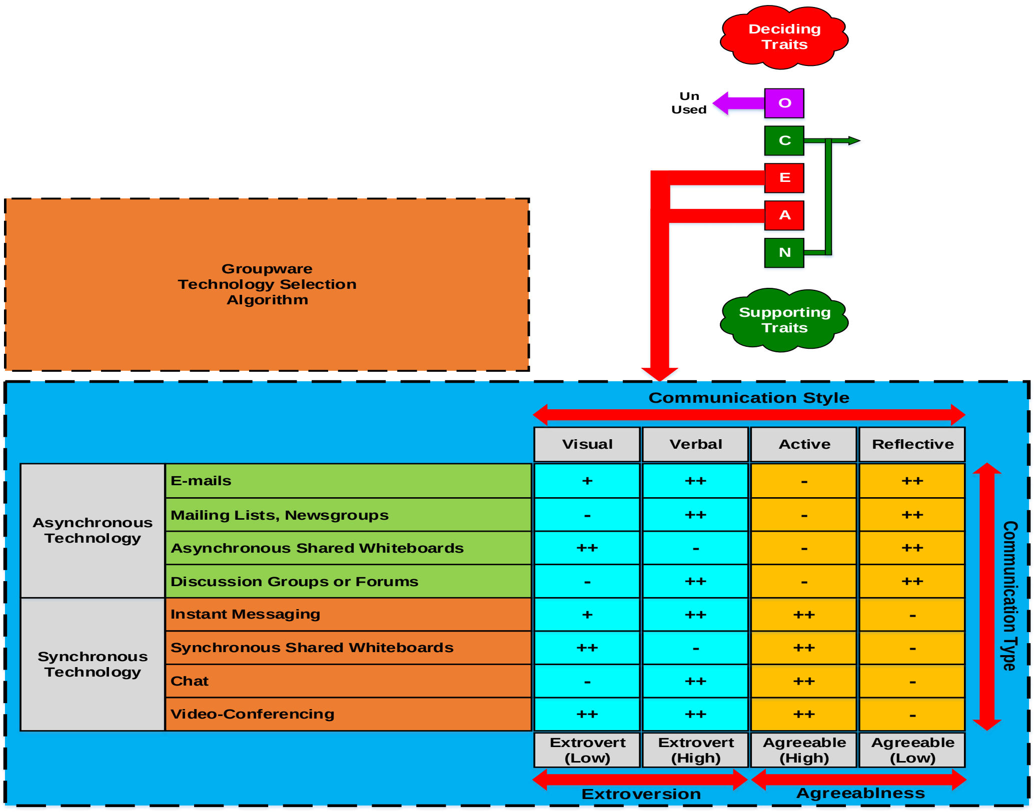


Figure-4.27 Support/Oppose Analysis

The openness trait is not used during groupware tools selection process as is already explained. The values of "E" and "A" are taken as deciding traits, which are used to select the most suitable elicitation groupware tool according to user personality traits. If the value of the trait "E" is high, then verbal communication mode/method is selected. However, if the value of the trait "E" is low, then visual communication mode/method is selected. Similarly, if the value of the trait "A" is high, then active communication mode/method is selected. However, if the value of the trait "A" is low, then reflective communication mode/method is selected. If the temporal diversity or cultural diversity or linguistic diversity is low, then the synchronous communication is recommended or asynchronous communication is recommended. Consider the given figure-4.28, which shows the traits mapping for groupware tools selection.



		Visual	Verbal	Active	Reflective
Asynchronous Technology	E-mails	+	++	-	++
	Mailing Lists, Newsgroups	-	++	-	++
	Asynchronous Shared Whiteboards	++	-	-	++
	Discussion Groups or Forums	-	++	-	++
Synchronous Technology	Instant Messaging	+	++	++	-
	Synchronous Shared Whiteboards	++	-	++	-
	Chat	-	++	++	-
	Video-Conferencing	++	++	++	-
		Extrovert (Low)	Extrovert (High)	Agreeable (High)	Agreeable (Low)

Figure-4.28 Personality Traits Analysis for RE Groupware Tools Selection Process

There is an elicitation groupware tools selection algorithm, which is used during the personality traits analysis stage of the process. The elicitation groupware tools selection algorithm used during personality traits analysis is given below:

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Groupware Technology Selection Algorithm

Assumption-1: Global-Context (GSD) is considered as the main context/scenario, which defines the geological constraints for groupware tools, based interaction. Hence, GSD context has Primary (Highest) Priority.

Assumption-2: Situational-Context is considered as the sub-context/scenario, which defines the feasibility (logistic constraints) for groupware tools selection and support. The situational context lies inside the GSD context and has Secondary (Next-Highest) Priority.

Assumption-3: User-Preference has High Priority as compared to Analyst-Preference because it is a user-centric framework.

Assumption-4: User-Personality has the High Priority as compared to User-Preference because personality better guides about Groupware tools suitability and selection as compared to User-Preference.

Let G_{Pr} is a set of groupware tools left after applying Contextual Filtering (CF) and Preference Filtering (PF)

Where $G_{Pr} \neq \phi$ (Where ϕ is an empty set), Also $G_{Pr} = (G_{Co} \text{ or } G_{Us}) \leq G_{En} \leq G_{Gl} \leq G_{Un}$

Phase-1 (Groupware Classification Phase)

Step-1 (Groupware Super-Classification): Classify G_{Pr} into following two main categories/groups:

Type-1: Asynchronous Technology (Asyn)

Type-2: Synchronous Technology (Syn)

G_{Pr} would contain Asynchronous Tools (if temporal overlap is Low) or Synchronous Tools (if temporal overlap is High) or Mixed (Asynchronous + Synchronous) Tools (if temporal overlap is Medium)

Step-2 (Group-Based Sub-Classification): Sub-classify Asyn and Syn Groupware Tools into following two pair based Sub-categories/Sub-groups:

Type-1: Visual/Verbal Tools

Type-2: Active/Reflective Tools

Step-3 (Sub-Types Based Sub-Classification): Further, sub-classify Asyn and Syn Tools into Sub-Types/Sub-categories/Sub-groups (like Emails, Whiteboards, Instant Messaging, Conferencing, Newsgroups, and Discussion Forums etc.)

Phase-2 (Personality Traits Mapping Phase)

Step-4 (Calculate Net Support Factor NSF): Get first Support Factor SF-1 (SF-1A, SF-1S) from situational context analysis. Check Value of Trait ‘C’ and Trait ‘N’ of OCEAN pattern of Elicit/User personality to calculate second Support Factor (SF-2) as given below.

Iteration-1: Assign Supporting/Opposing attribute to Trait 'C' and Trait 'N'

If C = High: Trait is Supporting & If C = Low: Trait is Opposing

If N = Low: Trait is Supporting & If N = High: Trait is Opposing

Iteration-2: Find Cumulative Effect of Supporting/Opposing attribute to find the Support Factor (SF-2):

Set = {C , N} Where C/N = Binary

{0 , 0} = {**O**ppose , **S**upport}

{0 , 1} = {**O**ppose , **O**ppose}

{1 , 0} = {**S**upport , **S**upport}

{1 , 1} = {**S**upport , **O**ppose}

Support Factoring

{O , S} = Average

{O , O} = Worst

{S , S} = Best

{S , O} = Average

Iteration-3: Classify Support Factors into following three types:

Type-1 (SF-T1) = Best = {S, S}

Type-2 (SF-T2) = Worst = {O, O}

Type-3 (SF-T3) = Average = {(O, S), (S, O)} = {O, S}

Support Factor (SF-2)

{S+S} = Best

{O+O} = Worst

{S+O} = Average

Iteration-4: Calculate Net Support Factor (NSF) using SF-1 (SF-1A/SF-1S) and SF-2 as follows: Let Best = B, Worst = W, Average = A

{SF-1, SF-2}

{B, B} = Best

{B, W} = Average

{B, A} = Average

{W, B} = Average

{W, W} = Worst

{W, A} = Average

{A, B} = Average

{A, W} = Average

{A, A} = Average

Net Support Factor (NSF)

{B, B} = Best (NSF-Best)

{W, W} = Worst (NSF-Worst)

{Others} = Average (NSF-Average)

Step-5 (Map Deciding-Traits to Categorize Groupware Tools): Check Value of Trait 'E' and Trait 'A' of OCEAN Pattern of Elicit/User Personality.

If E = High: Map-in Verbal Tools

If E = Low: Map-in Visual Tools

<u>For Temporal Diversity = Low/High</u>

GSD > Trait “A”: Trait “A” Values Ignored

GSD Decides Asynchronous/Synchronous Tools Selection

<u>For Temporal Diversity = Medium</u>

GSD < Trait “A”: Trait “A” Values Considered

Trait “A” Decides Asynchronous/Synchronous Tools Selection

If A = High: Map-in Active Tools

If A = Low: Map-in Reflective Tools

Phase-3 (Suitable Groupware Tools Selection Phase)

Step-6 (Select Suitable Groupware Tools): Select the most suitable groupware tool by considering the values of Temporal Diversity “TD”, Trait ‘E’ and Trait ‘A’ of OCEAN Pattern of Elicit/User Personality.

<u>For Temporal Diversity = Low</u>

TD_Low {E, A} = Selected Groupware

TD_Low {L, L} = Visual Synchronous Groupware

TD_Low {L, H} = Visual Synchronous Groupware

TD_Low {H, L} = Verbal Synchronous Groupware

TD_Low {H, H} = Verbal Synchronous Groupware

For Temporal Diversity = Medium

TD_Medium {E, A} = Selected Groupware

TD_Medium {L, L} = Visual Asynchronous Groupware

TD_Medium {L, H} = Visual Synchronous Groupware

TD_Medium {H, L} = Verbal Asynchronous Groupware

TD_Medium {H, H} = Verbal Synchronous Groupware

For Temporal Diversity = High

TD_High {E, A} = Selected Groupware

TD_High {L, L} = Visual Asynchronous Groupware

TD_High {L, H} = Visual Asynchronous Groupware

TD_High {H, L} = Verbal Asynchronous Groupware

TD_High {H, H} = Verbal Asynchronous Groupware

Step-7 (Calculate Net-Effectiveness of Selected Groupware Tools): Assign Net Support Factor (NSF) with Selected Groupware Tools to Assess Groupware Tool Net-Effectiveness.

Groupware Tool Net-Effectiveness (GTNE) = Selected Groupware Tool (SGT) + Net Support Factor (NSF)

Best GTNE (Best Scenario) = SGT + NSF-Best

Worst GTNE (Worst Scenario) = SGT + NSF-Worst

Average GTNE (Average Scenario) = SGT + NSF-Average

****

4.9 PROPOSED FRAMEWORK SIGNIFICANCE

The main concern of this research is to provide a user-centric requirements elicitation framework, which is incorporated with user personality traits (along with other relevant factors of requirements elicitation in global software development) for global software development teams. The envisioned user-centric framework is expected to provide an improved mechanism for requirements elicitation process for those environments where the software development team as-well-as product users are geographically distributed in different parts of world. The interactions between software development teams and product users become a more challenging task in offshore projects due to the variations in geological locations, time zones, languages and culture of participants as compared to traditional in-house software development contexts.

The proposed framework will help the software industry to understand the impact/effect of user-centeredness on requirements elicitation process for global software development teams. The proposed framework will help the software industry to understand the general impact/effect of personality traits factor on requirements elicitation process for global software development teams. The proposed framework will help the software industry to understand the specific impact/effect of user personality traits on requirements elicitation process for global software development teams. The proposed framework will contribute in improvement of software development process by improving requirements elicitation process for global software development teams. The proposed framework will serve as an asset for software industry to plan the most effective/productive requirements elicitation contexts for global software development teams.

4.10 PROPOSED FRAMEWORK APPLICATIONS

The proposed framework is a requirements elicitation framework for global software development teams. The proposed framework can be applied for the requirements elicitation process managed by globally distributed software development teams with internal team distributions of any type including low geographical distributions, medium geographical distributions and high geographical distributions. The proposed framework can be applied for the requirements elicitation process of any kind of software development projects coordinated by geographically distributed software development teams. The proposed framework would be equally applicable and beneficial for traditional in-house software development teams with minor customizations in its contextual parameters. This customization would enable software industry to use the proposed framework as a valuable asset that would serve as a requirements elicitation team selection tool/technology for global software development teams. The proposed framework can be integrated in requirements elicitation tools/technologies used by software development industry to improve the overall elicitation context by engaging elicitation sessions with product users/stakeholders using most suitable elicitation teams, techniques and tools.

The proposed framework can be applied on traditional as well as globally distributed software development projects to get the following benefits:

1. The proposed framework will help the software industry to understand the impact of user-centeredness on requirements elicitation process for global software development teams.

2. The proposed framework will help the software industry to understand the impact of user personality traits on requirements elicitation process for global software development teams.

3. The proposed framework will contribute in improvement of software development process by improving requirements elicitation process for global software development teams.

4. The proposed framework will serve as an asset for software industry to plan the most productive requirements elicitation contexts for global software development teams.

4.11 PROPOSED FRAMEWORK ASSESSMENT

The proposed framework has been assessed using two levels of evaluation processes including an initial controlled experiment approach using academic setups (pilot testing) and a final real-time industrial experiment using industrial setups (real study). This two levels assessment ensures a comprehensive testing of the proposed framework using hypothetical projects as well as real-time industrial projects under development by different software development teams working from different parts of the world. The assessment of the proposed framework was planned in such a manner that all internal processes, algorithms and techniques of the framework were comprehensively assessed as per guidelines provided by the software development industry.

4.11.1 Controlled Experiment (Pilot Study)

The academic controlled experiment was performed on a group of hundred students belonging to an undergraduate degree program of department of software engineering in a chartered university. The sample was selected from the students of a *Bachelor of*

Science in Software Engineering (BSSE) program who had already passed the subject of software requirements engineering successfully and had a substantial knowledge of the requirements elicitation process and software requirements specifications documentations using IEEE standard practice. The students were randomly divided into different groups of equal size and subsequently hypothetically working software development teams were established by merging randomly selected two groups into one software development team. All software development teams were asked to act like a global software development teams to work on two different software development projects using two different development iterations. In the first iteration, the students were given a fixed time margin to elicit and document the requirements of a hypothetical project using traditional global software development practices. In order to perform the requirements elicitation during first project, the group-1 of the team was asked to act like an analyst team while the group-2 was asked to act like a user team. In the second iteration, the students were again given a fixed time margin (equal to project-1 time margin) to elicit and document the requirements of a second hypothetical project using proposed requirements elicitation framework. In order to perform the requirements elicitation during second project, the group roles were reversed to remove the group-based biasness and the group-1 of the team was asked to act like a user team while the group-2 was asked to act like an analyst team. After the completion of the both iterations, the results of both iterations were translated from qualitative attributes to quantitative values using expert opinions. At the end, the quantitative results of both iterations were compared to see the improvements in the requirements elicitation process using the proposed requirements elicitation framework.

4.11.2 Industrial Experiment (Real Study)

The industrial real-time experiment was performed on the real software development projects running in three different global software development companies. The software development companies were selected on basis of the requirements elicitation team geographical distributions and nature of the software development projects. The first company was based on the low geographical distribution in requirements elicitation teams where analyst team members were in one country while the user team members were in another country. This company was working on an android game development project using offshore software development teams. The second company was based on the medium geographical distribution in requirements elicitation teams where analyst team members were in one country while the user team members were distributed in multiple countries. This company was working on an android application development project using offshore software development teams. The third company was based on the high geographical distribution in requirements elicitation teams where analyst team members were in multiple countries as well as the user team members were also in multiple countries. This company was working on a web development project using offshore software development teams. Each company was asked to develop the requirements specification document for their project using two iteration where first iteration was run without using proposed framework while the second iteration was run with using the proposed framework. After the completion of the both iterations, the results of both iterations were translated from qualitative attributes to quantitative values using expert opinions. At the end, the quantitative results of both iterations were compared to see the improvements in the requirements elicitation process using the proposed requirements elicitation framework. The double blindness technique was used in the research methodology during controlled experiment as well as during industrial experiment to reduce the effects of biasness on the generated results of requirements elicitation process.

4.12 CHAPTER SUMMARY

This chapter presents the complete design of the proposed framework by initially introduces its different aspects. The chapter discusses the base of the proposed framework in which three base articles have been discussed which make the foundations for the proposed framework. These three articles represent three base aspects of proposed framework including requirements elicitation aspect, global software development aspect and situational requirements engineering aspect. The chapter then discusses the theory of the proposed framework in which different theoretical aspects of the framework have been discussed. The theory of the proposed framework introduces the alignment of framework design and conceptualization with already available theory of models and frameworks in domain of software engineering. The chapter then presents different views of the proposed framework including framework abstract view and framework process view. The chapter then presents the framework structural hierarchy and framework execution workflow along with its internal processes and algorithms. The chapter then presents the framework significance, applications and assessment. The abstract view of the proposed framework presents the framework in its simplest form by showing only top-level inputs and outs of the framework along with its internal main stages of work. The framework process view presents the complete hierarchy of different processes running in different phases of the framework during the whole requirements elicitation process. The framework structural hierarchy presents the complete details of linkages and associations between different stages of the framework along with their phases, processes, activities, tasks and sub-tasks. The framework execution workflow presents the different top-level work segments, which execute in the described sequences to accomplish the whole process of requirements elicitations successfully. The framework processes and algorithms present a set of requirements elicitation team selection, technique selection and groupware technology section processes and algorithms. This completely describes the design of these processes and algorithms using personality assessment procedures to customize the requirements elicitation process as per user personality aspects to facilitate him. The chapter also presents the significance of the proposed framework along with is application areas and assessment methods used during its academic evaluation as well as industrial evaluation.

CHAPTER FIVE

FRAMEWORK EVALUATION

This chapter presents the complete evaluation process of the proposed framework and consequent results obtained during initial evaluation phase and final evaluation phase of the process. The evaluation of the proposed framework was carried-out by using two-stage evaluation process based on an initial pilot study proceeded by a final industrial study. Accordingly, the initial evaluation of the proposed framework was accomplished using a controlled experiment method (pilot test) using academic setup as study sample. The final evaluation of the proposed framework was accomplished using an industrial experiment method (industrial test) using industrial setups as study sample. The complete details of the pilot study and industrial study are given in the next sections along with detailed analysis of obtained results.

5.1 FRAMEWORK ACADEMIC EVALUATION (PILOT STUDY)

The framework academic evaluation refers to the controlled experiment (pilot study) performed using students as population. In pilot study, the selected population for evaluation of proposed framework was comprised of undergraduate students of *Bachelor of Science in Software Engineering (BSSE)* program in department of software engineering of a charted university. The software engineering department of selected university had a total strength of more than one thousand students in its undergraduate programs. The majority of the undergraduate students belong to the nearby locality of the university while a small group of students belong to the remote areas of the country and stay in hostels located near the university campuses.

The students of undergraduate programs go through the basic courses of computer sciences and software engineering along with courses from social sciences. Hence, the students were capable of demonstrating the technical skills of software engineering domain along with personality building soft skills needed to interact and collaborate with members of society. Additionally, the students of software engineering program also go through the specialized courses of software engineering including software requirements engineering, software design and architecture, software quality assurance, software verification and validation, software project management and software testing etc. The mainstream of population selected for trial test of proposed framework was belonging to the software engineering program where all students were already gone through the course of software requirements engineering.

Accordingly, a group of only 100 students (out of more than 1000 population) was selected from whole department of software engineering who already had a substantial amount of knowledge of software requirements engineering domain and a deep understanding of requirements elicitation process. Each student of the selected sample also remained participant in the projects relating to software requirements elicitation process and software requirements specifications according to IEEE standard Std. 830 (IEEE Standards Association, 2009) for SRS development. Hence, each student was well-aware of the IEEE practices of documenting functional requirements, non-functional requirements and graphical user interface requirements in accordance with IEEE standard Std. 830 (R2009). Consider the given figure-5.1, which explains the whole process of academic evaluation of the proposed framework along with complete details of training process executed during evaluation process.

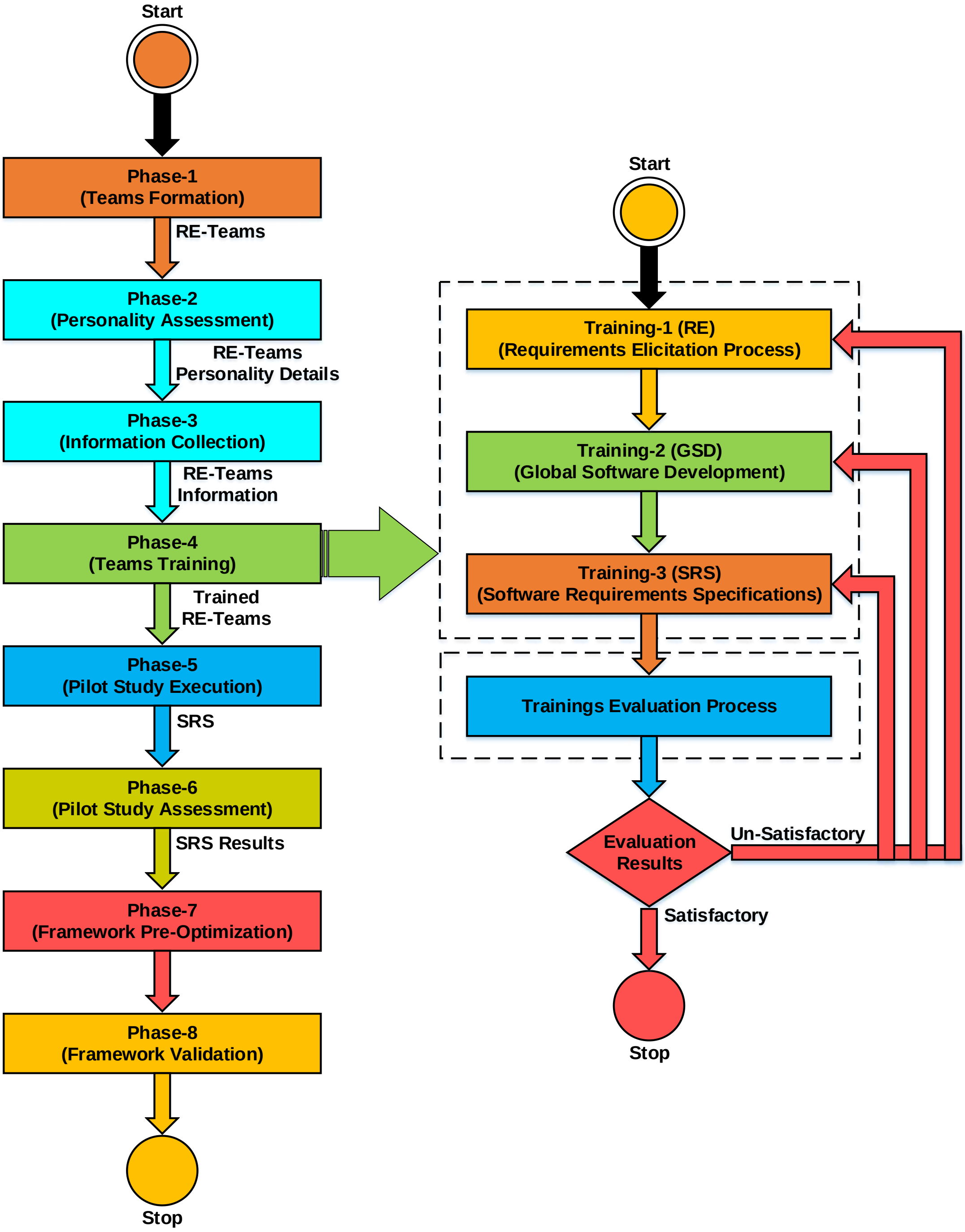

Figure-5.1 Framework Academic Evaluation (Pilot Study) Process

The academic evaluation process was systematically designed to evaluate the proposed framework using a controlled experiment using a population sample of 100 students of undergraduate program. ***In phase-1***, the student's teams were made by randomly selecting ten team members for each team. Each team was then divided into two groups (group-1 & group-2) of five students each. ***In the phase-2***, student's personality assessment was performed using a standard big-five IPIP-50 questions-based personality assessment test. The results of this personality assessment test were used to customize the pilot study activities (as guided by proposed framework) according to user personality traits to make it user-centric process. ***In the phase-3***, information collection forms were used to collect the personal information about participants, participants work information, project information and stakeholder's information. ***In the phase-4***, the teams were given different trainings about requirements elicitation process, global software development context and software requirements specification document development process. After the completion of these trainings, the participant's knowledge about these three aspects was evaluated by using three training evaluation forms. The trainings were revised for some teams depending upon the evaluation results of teams. ***In the phase-5***, the pilot study execution was performed by starting requirements elicitation process and documenting elicited requirements using IEEE SRS standard. The pilot study execution was performed in form of two different requirements elicitation iterations. The first iteration was executed without using proposed framework and SRS-1 of project-1 was developed. The second iteration was executed using proposed framework and SRS-2 of project-2 was developed. ***In phase-6***, the pilot study assessment was performed to assess the quality of SRS-1 and SRS-2 according to IEEE standard Std. 830 (R2009). The results of the pilot study were documented using different types of tables for analysis and discussion purpose. ***In the phase-7***, the proposed framework design and assessment tools were optimized/customized to better serve in the industrial study of proposed framework. ***In the phase-8***, the framework validation was performed in accordance with the precustomizations done in previous phase and taking feedback from participants of both studies.

5.1.1 Pilot Study, Sample Characteristics

Consider the given table-5.1, which shows the main characteristics of the selected sample chosen from population for the academic evaluation (pilot study) of the proposed framework. The mentioned sample have been taken from a population of undergraduate students of a chartered university of Pakistan.

Table-5.1 Pilot Study, Sample Characteristics

Sr#	Parameters	Value/Characteristics
1.	Sampling Strategy Used	Probability Sampling Strategy
2.	Sampling Methods Used	Clustering Sampling Method
3.	Sample Size	100 Students
4.	Sample Degree	Bachelor of Science in Software Engineering (BSSE)
5.	Sample Semester	Sixth (6^{th})
6.	Sample Class Grades	Mixed (Randomly Selected)
7.	Sample Gender Type	Mixed (Male & Female)
8.	Sample Gender Ratio	Variant (Not Fixed)
9.	Sample Geographical Distribution	Prototypic Five Countries Considered
10.	Sample Cultural Diversity	Prototypic Medium Diversity Considered
11.	Sample Temporal Diversity	Prototypic Medium Diversity Considered
12.	Sample Linguistic Diversity	Prototypic Medium Diversity Considered

13.	Sample Professional Skills Required	Not Fixed (Randomly Selected)
14.	Sample General Pre-requisite Criteria	Introduction to Software Engineering Course Passed Successfully
15.	Sample Specific Pre-requisite Criteria	Software Requirements Engineering Course Passed Successfully

5.1.2 Pilot Study, Experiment Characteristics

Consider the given table-5.2, which shows the characteristics of the experiment conducted during the academic evaluation (pilot study) of the proposed framework. As described already, the presented controlled experiment was performed on a sample of 100 students of undergraduate program at a university in Pakistan.

Table-5.2 Pilot Study, Experiment Characteristics

Sr#	Parameters	Values/Characteristics
1.	Experiment Overall Duration	Two Months (About Eight Weeks)
2.	Experiment Total Projects	Two Projects (Project-1 & Project-2)
3.	Experiment Projects Complexity	Medium Level Complexity
4.	Experiment Projects Domain	Web Development Projects
5.	Experiment Projects Tasks	Requirements Elicitation and Specifications
6.	Experiment SRS Standard Used	IEEE SRS Standard Std. 830-1998 (R2009)
7.	Experiment Evaluators Involved	Two External Evaluators
8.	Experiment Evaluator Profiles	One Evaluator from Academics One Evaluator from Industry
9.	Experiment Evaluation Method	Double Blindness Method Used
10.	Experiment Evaluation Tool	Six Data Collection Forms Six Data Analysis Forms

5.1.3 Pilot Study, Scenario Characteristics

The pilot study was executed using undergraduate students who were put in a prototypic GSD environment to perform all communications and conversations in accordance with the GSD project modes. In this regard ten prototypic requirements elicitation teams were made with equal number of members in each team. Consider the given table-5.3, which explains the different characteristics of composed prototypic requirements elicitation teams used during the pilot study of the proposed framework.

Table-5.3 Pilot Study, Prototypic RE Teams Characteristics

Sample Size	100 Students
Total Teams	10 (T0, T1, T2, T3, T4, T5, T6, T7, T8, T9)
Team Size	10 Members
Team Split	Two Groups (Group-1, Group-2)
Group Split	**Group-1:** Five Students (1 Leader, 4 Members) **Group-2:** Five Students (1 Leader, 4 Members)
Group Roles	**Role-1:** Analyst Team **Role-2:** User Team
Teams Compositions	**Analyst Team:** 1 Analysts, 2 Members, 2 Recorders **User Team:** 1 Head User, 4 Member Users
Teams Work Iteration-1	Doing RE-GSD Without Using Proposed Framework **Group-1** (Analyst Team), **Group-2** (User Team)
Teams Work Iteration-2	Doing RE-GSD Using Proposed Framework **Group-1** (User Team), **Group-2** (Analyst Team)
Analyst Team Dispersion	**Moderate-Scenario** considered, where all members of analyst team belong to three different geological location/countries.
User Team Dispersion	**Worst-Scenario** considered, where all members of user team belong to different geological locations/countries.
Analyst-Team Geological Positions	Country-1 (Syria): Recorder-2 Country-3 (Pakistan): Analyst, Member-1, Recorder-1 Country-5 (Malaysia): Member-2

User-Team Geological Positions	Country-1 (Syria): User-1 Country-2 (Saudi Arabia): User-2 Country-3 (Pakistan): User-3 Country-4 (Indonesia): User-4 Country-5 (Malaysia): User-5
Team Members Cultural Patterns	Country-1 (Syria): Cultural Pattern-1 Country-2 (Saudi Arabia): Cultural Pattern-2 Country-3 (Pakistan): Cultural Pattern-3 Country-4 (Indonesia): Cultural Pattern-4 Country-5 (Malaysia): Cultural Pattern-5
Reference Country	Country-3 (Pakistan): Taken as Base Country with GMT+5
GMT Time Shift	1-6 Hours (GMT+2, GMT+3, GMT+5, GMT+7, GMT+8)

Consider the given figure-5.2 which shows the structure of each team of the pilot study. Each team was comprised of ten members, which were further split-up into two major groups (Analyst Team/Group and User Team/Group) where each group was comprised of randomly selected five members. The details of responsibilities of each team member are shown in the given figure. The participants of these prototypic requirements elicitation teams were allowed to perform communications using only GSD context based communicational channels so that the participants try to realize the real time constraints of GSD work environments.

Consider the given figure-5.3, which explains the communication channels/tools and mechanisms that were allowed to requirements elicitation teams during the pilot study experiment. The pilot study teams were allowed to use only Gmail communications as asynchronous communications tool and WhatsApp and landline communications as synchronous communication tools.

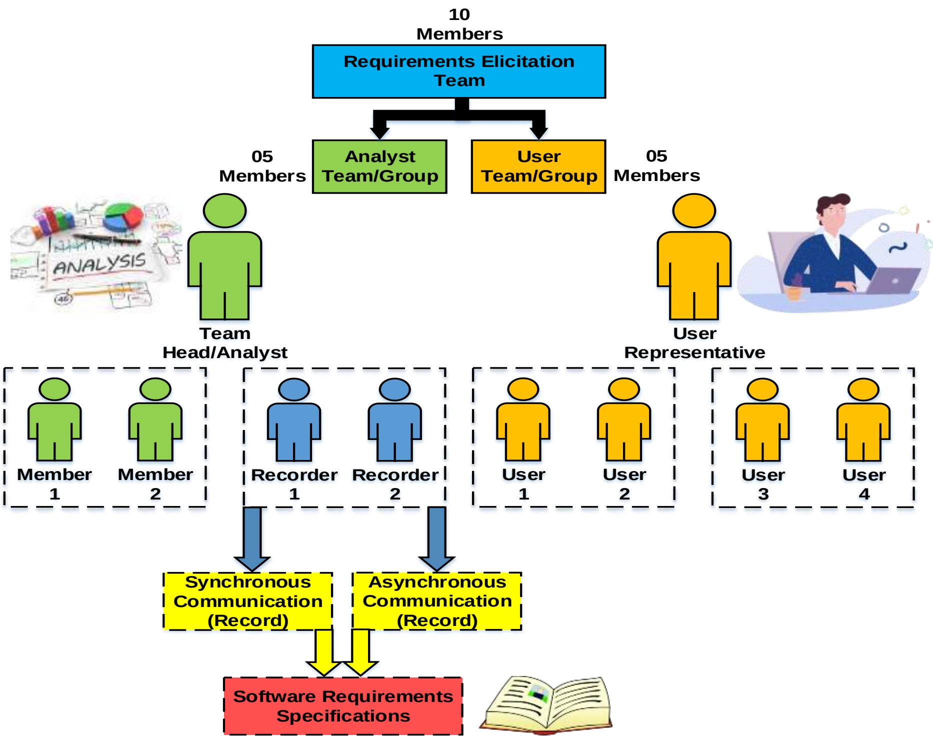

Figure-5.2 Details of Prototypic Software Teams

In case of WhatsApp, communication groups were created for each prototypic requirement elicitation team with strict control and monitoring of conversations. The teams were allowed to use WhatsApp as communication tool during only specified time intervals (reflecting to team members overlapping time durations).

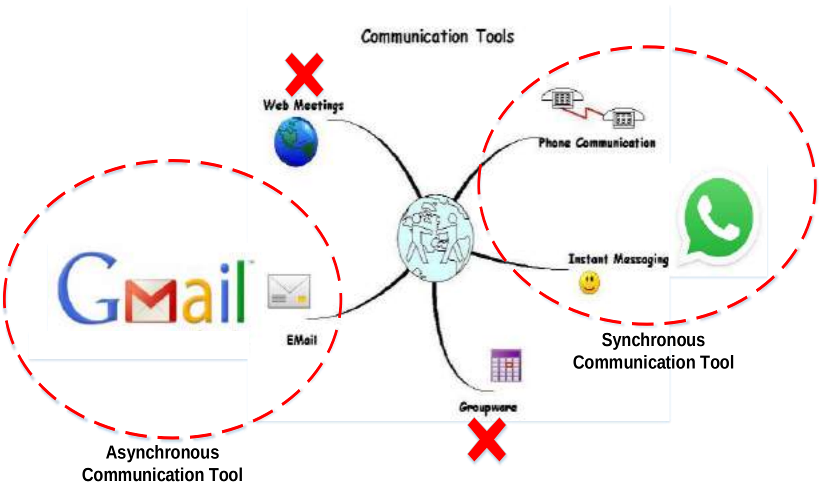

Figure-5.3 Communication Tools Used in Pilot Study

Consider the given figure-5.4, which explains the details of the GSD context assigned to pilot study team members. The GSD context assigned to all prototypic requirements elicitation teams was chosen as moderate/medium level geographical distribution context comprised of team members distributions among five different countries of world including Syria (GMT+2), Saudi Arabia (GMT+3), Pakistan (GMT+5), Indonesia (GMT+7) and Malaysia (GMT+8). The Pakistan was chosen as the base country for all kind of team customizations and works. The office timings of 08:00am to 04:00pm were taken as assumed office timings for the team members sitting at the base country of Pakistan. Hence, all kinds of timing overlapping and working hours were taken between these starting and ending time intervals of base country. In the given context, the analyst team was prototypically distributed in such a way that analyst, member-1 and recorder-1 were assumed to be in base country of Pakistan while recorder-2 was assumed to be sitting in Syria and member-2 was assumed to be sitting in Malaysia. In case of user teams, all team members were assumed to be distributed in all five countries selected for pilot study context.

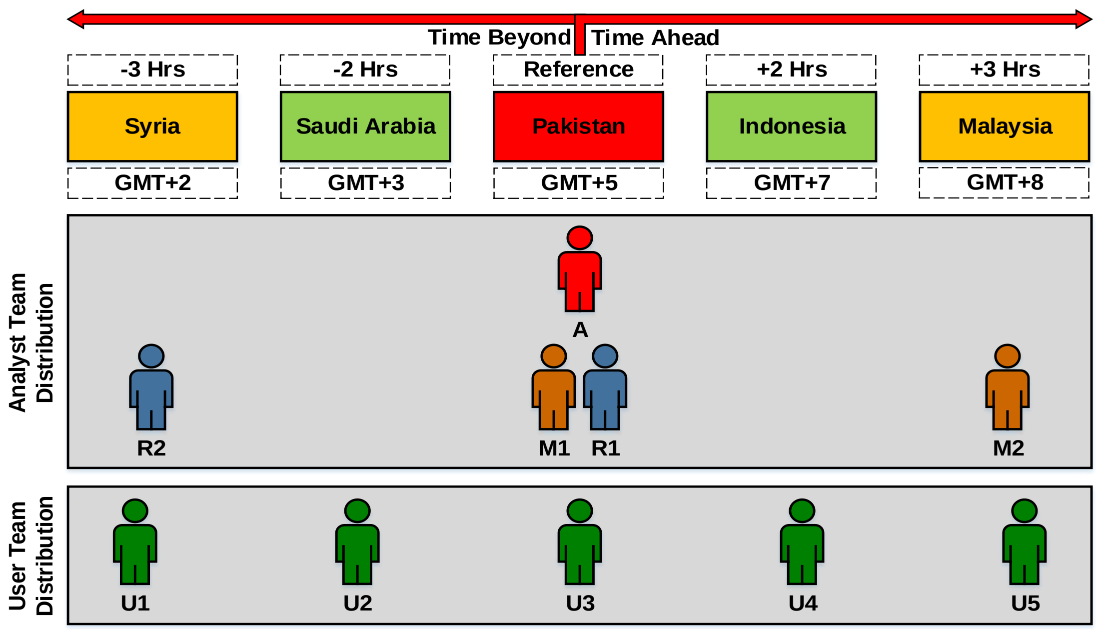

Figure-5.4 Assumed GSD Context for Pilot Study Teams

Consider the given figure-5.5, which explains the process of calculations of temporal dispersion/overlapping between team members of all teams assumed to be operating from five different countries of the world. The same process is recommended to calculate the temporal overlap of team members for real life GSD context of projects running in industry. A temporal overlap of less than or equal to 1-hour was taken (assumed) as low temporal overlap between team members during pilot study experiment. A temporal overlap of greater than 1-hour and less than or equal to 4-hours was taken (assumed) as medium temporal overlap between team members during pilot study experiment. A temporal overlap of greater than 4-hours was taken (assumed) as high temporal overlap between team members during pilot study experiment. Accordingly, the temporal overlap of the assumed GSD context was calculated to be 2 hours, which represents the temporal overlap of medium value as is shown in the given figure.

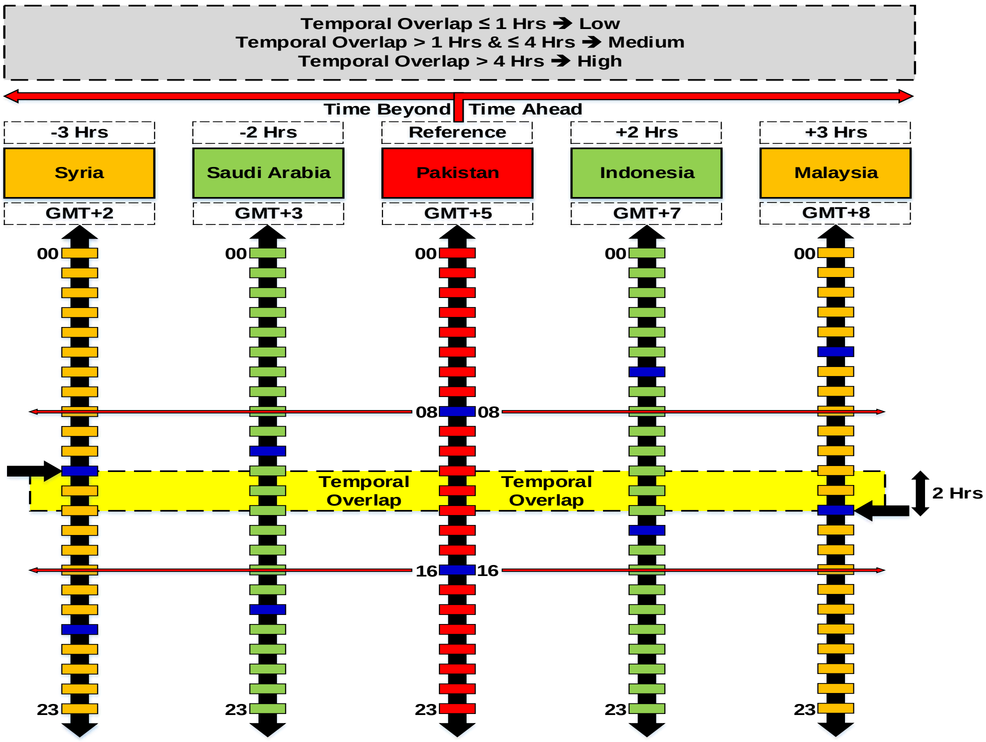

Figure-5.5 Temporal Overlap Calculations for Pilot Study Teams

5.1.4 Pilot Study, Results Analysis

During the first iteration of the pilot study work, the prototypic requirements elicitation teams (T0 to T9) were asked to perform requirements elicitations process without using proposed framework and document the elicited requirements of the assigned system (project-1) using IEEE SRS standard. During first iteration of study, the group-1 of each team was assigned the role of "Analyst Team" while the group-2 was assigned the role of "User Team". Afterwards, the second iteration of the study was performed in which team roles were swapped to minimize the team experience biasness and a new project (project-2) was assigned to teams to also minimize the project familiarity biasness. In the second iteration the group-1 of each team was assigned the role of "User Team" while the group-2 was assigned the role of "Analyst Team". In second iteration, the teams were asked to use the proposed framework for requirements elicitation process and document the elicited requirements using the same IEEE standard. In this way, each team documented two SRS including SRS-1 made without using proposed framework and SRS-2 made with using the proposed framework. The expert judgment methodology was used to evaluate the both SRS documents developed by each team. Accordingly, both SRS of all teams were sent to external evaluators for numerical grading to transform the qualitative data into quantitative data for further analysis. The chosen experts were asked to grade each SRS on basis of 100 marks that were equally distributed among eight quality attributes of IEEE SRS standard Std. 830 (R2009). One external expert was chosen from academics (university professor of software engineering domain) while the other external expert was chosen from industry (software development company). Each SRS was internally graded as chapter wise and as IEEE quality attributes wise to more precisely judge the outcomes of the requirements elicitation process.

Consider the given table-5.4, which has been used to show the details of the grades assigned by both evaluators to both SRS of each team. The table also shows the team improvements gained during SRS-2 development as compared to SRS-1 development and all teams' average improvements for both evaluators. The table also shows all team's overall improvements by using proposed framework for requirements elicitations and documentation.

Table-5.4 Pilot Study, Overall Results (Evaluators Wise)

Pilot Study Overall Results Comparison				
Team ID	**SRS1 Results** (Without Framework)	**SRS2 Results** (With Framework)	**Team Improve**	**Average Improve**
Evaluator-1 (Academic) Results				
Team T0	59.0	72.5	+13.5%	**+11.2%**
Team T1	55.0	67.0	+12.0%	
Team T2	67.0	84.0	+17.0%	
Team T3	55.0	77.5	+22.5%	
Team T4	58.0	72.5	+14.5%	
Team T5	60.5	55.5	-05.0%	
Team T6	66.0	78.0	+12.0%	
Team T7	57.0	69.5	+12.5%	
Team T8	78.0	70.5	-07.5%	
Team T9	49.0	69.5	+20.5%	
Evaluator-2 (Industry) Result				
Team T0	65.5	83.0	+17.5%	**+15.5%**
Team T1	73.0	88.5	+15.5%	
Team T2	58.5	73.0	+14.5%	
Team T3	62.5	80.0	+17.5%	
Team T4	62.5	84.5	+22.0%	
Team T5	67.0	75.5	+08.5%	
Team T6	70.0	89.5	+19.5%	
Team T7	44.5	65.0	+20.5%	
Team T8	62.0	70.5	+08.5%	
Team T9	64.5	75.5	+11.0%	
All Teams Overall Average Improvement				**+13.4%**

A total of 13.4% quality improvement (in terms of IEEE defined eight quality attributes of SRS) in requirements elicitation process was observed during the second iteration of study based on the use of proposed framework for requirements elicitations.

Consider the given table-5.5A, which has been used to show the results of evaluations of SRS-1 and SRS-2 of each team by both evaluators (evaluator-1 from academics and evaluator-2 from industry). An average value of SRS-1 and SRS-2 have been taken from results of both evaluators to minimize the evaluator's biasness effect. The table shows the overall average of all team's grades of both SRS and calculates the overall improvements by all teams during the second iteration of work using proposed framework. The results of this table have also been shown as a graph in figure-5.6. Also, the given table-5.5B provides the detailed statistical analysis of data obtained from whole data set of all teams to calculate mean value, median value, mode value and standard deviation value.

Table-5.5A Pilot Study, Overall Results (Teams SRS Wise)

SRS	Evaluator	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
SRS1	**Evaluator-1**	59.0	55.0	67.0	55.0	58.0	60.5	66.0	57.0	78.0	49.0
	Evaluator-2	65.5	73.0	58.5	62.5	62.5	67.0	70.0	44.5	62.0	64.5
	Avg (E1+E2)/2	**62.25**	**64.00**	**62.75**	**58.75**	**60.25**	**63.75**	**68.00**	**50.75**	**70.00**	**56.75**
	All Teams Avg (Avg1)	**61.7%**									
SRS2	**Evaluator-1**	72.5	67.0	84.0	77.5	72.5	55.5	78.0	69.5	70.5	69.5
	Evaluator-2	83.0	88.0	73.0	80.0	84.5	75.5	89.5	65.0	70.5	75.5
	Avg (E1+E2)/2	**77.75**	**77.50**	**78.50**	**78.75**	**78.50**	**65.50**	**83.75**	**67.25**	**70.50**	**72.50**
	All Teams Avg (Avg2)	**75.1%**									

All Teams Individual Imp	**15.50**	**13.50**	**15.75**	**20.00**	**18.25**	**01.75**	**15.75**	**16.50**	**00.50**	**15.75**
Overall Imp (Avg2-Avg1)	**+13.4%**									

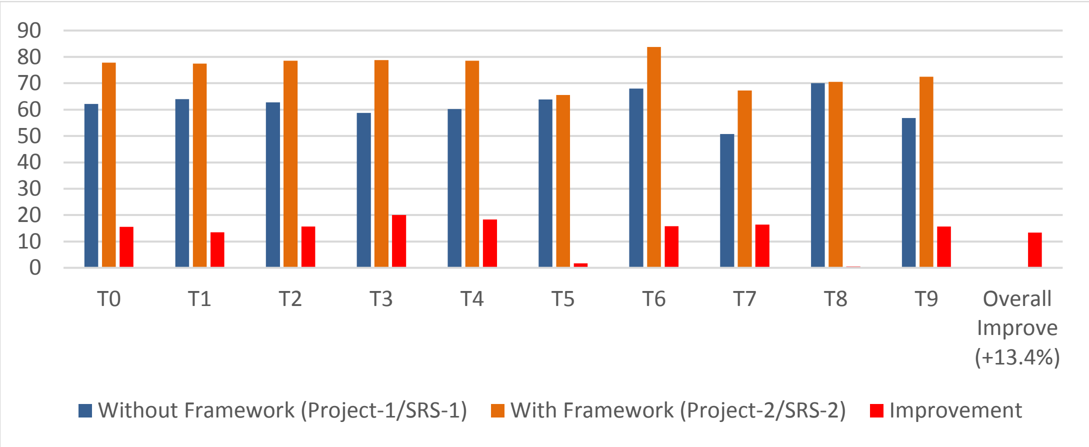

Figure-5.6 Pilot Study, Overall Results (Team-wise, SRS Improvements)

Table-5.5B Pilot Study, Statistical Analysis of Overall Results

SRS	Evaluator	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
SRS1	Evaluator-1	59.0	55.0	67.0	55.0	58.0	60.5	66.0	57.0	78.0	49.0
	Evaluator-2	65.5	73.0	58.5	62.5	62.5	67.0	70.0	44.5	62.0	64.5
	Avg1 (E1+E2)/2	62.25	64.00	62.75	58.75	60.25	63.75	68.00	50.75	70.00	56.75
SRS2	Evaluator-1	72.5	67.0	84.0	77.5	72.5	55.5	78.0	69.5	70.5	69.5
	Evaluator-2	83.0	88.0	73.0	80.0	84.5	75.5	89.5	65.0	70.5	75.5
	Avg2 (E1+E2)/2	77.75	77.50	78.50	78.75	78.50	65.50	83.75	67.25	70.50	72.50
All Teams Individual Imp		15.50	13.50	15.75	20.00	18.25	01.75	15.75	16.50	00.50	15.75
Mean, Median, Mode, Standard Deviation											
Ascending Sorted Values		0.5	1.75	13.5	15.5	15.75	15.75	15.75	16.5	18.25	20
		T8	T5	T1	T0	T2	T6	T9	T7	T4	T3
Mean Value		**13.40**									
Median Value		**15.75**									
Mode Value		**15.75**									
Standard Deviation		**06.66**									

Consider the table-5.6, which has been used to show the results of evaluations of all pilot study teams in form of chapter-wise results sheet. This table shows an overall improvement gained of 12.0% in chapter-2, 16.2% in chapter-3, 9.5% in chapter-4 and 13.5% in chapter-5 of the SRS by all teams of pilot study. This chapter is concerned with the overall system descriptions and hence, relates to overall system understandability. Therefore, improvement gained in this chapter is a direct reflection of stakeholder's system understandability developed during requirements elicitation process using proposed framework. The team-wise improvements results of this table have been shown in figure-5.7 while chapter-wise improvements results of this table have been shown in figure-5.8.

Table-5.6 Pilot Study, SRS Results (Chapter Wise)

Chapter	SRS (Evaluator)		T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
Chapter 2	SRS$_1$	E1	12.5	12.5	12.0	11.0	15.0	12.5	13.0	12.5	15.5	12.5
		E2	17.0	14.0	14.5	13.5	15.0	13.0	15.0	10.0	10.0	15.5
		Avg1	**14.8**	**13.2**	**13.2**	**12.2**	**15.0**	**12.8**	**14.0**	**11.2**	**12.8**	**14.0**
	SRS$_2$	E1	17.0	14.0	17.0	14.5	15.5	10.5	14.5	12.5	17.5	16.5
		E2	17.5	17.5	16.5	17.0	16.0	16.0	17.0	15.0	15.5	16.0
		Avg2	**17.2**	**15.8**	**16.8**	**15.8**	**15.8**	**13.2**	**15.8**	**13.8**	**16.5**	**16.2**
Imp (Avg2-Avg1)			**+2.4**	**+2.6**	**+3.6**	**+3.6**	**+0.8**	**+0.4**	**+1.8**	**+2.6**	**+3.7**	**+2.2**
All Teams Avg Imp (T0-T9)			**+2.4 ➔ (2.4/20)x100 = +12.0%**									
Chapter 3	SRS$_1$	E1	25.5	23.0	28.5	21.5	23.0	23.0	27.5	22.5	33.0	16.0
		E2	23.5	32.0	22.0	24.0	25.5	27.5	31.0	16.0	24.5	25.5
		Avg1	**24.5**	**27.5**	**25.2**	**22.8**	**24.5**	**25.2**	**29.2**	**19.2**	**28.8**	**20.8**
	SRS$_2$	E1	29.5	32.0	36.0	33.0	31.5	26.0	32.0	30.5	26.5	27.0
		E2	32.5	38.5	28.5	33.0	34.5	30.0	37.5	25.0	28.5	33.0
		Avg2	**31.0**	**35.2**	**32.2**	**33.0**	**33.0**	**28.0**	**34.8**	**27.8**	**27.5**	**30.0**
Imp (Avg2-Avg1)			**+6.5**	**+7.7**	**+7.0**	**+10.2**	**+8.5**	**+2.8**	**+5.6**	**+8.6**	**-1.3**	**+9.2**
All Teams Avg Imp (T0-T9)			**+6.5 ➔ (6.5/40)x100 = +16.2%**									
Chapter 4	SRS$_1$	E1	08.5	09.5	13.0	10.0	09.5	11.5	13.0	14.0	15.5	09.0
		E2	11.5	13.5	10.5	13.0	12.0	13.5	13.0	09.5	13.5	11.0
		Avg1	**10.0**	**11.5**	**11.8**	**11.5**	**10.8**	**12.5**	**13.0**	**11.8**	**14.5**	**10.0**

	SRS_2	E1	09.5	11.0	16.5	15.0	13.5	09.0	13.5	15.0	14.5	12.5
		E2	13.5	15.5	14.0	13.5	17.5	14.5	16.5	12.5	11.5	13.0
		Avg2	**11.5**	**13.2**	**15.2**	**14.2**	**15.5**	**11.8**	**15.0**	**13.8**	**13.0**	**12.8**
Imp (Avg2-Avg1)			**+1.5**	**+1.7**	**+3.4**	**+2.7**	**+4.7**	**-0.7**	**+2.0**	**+2.0**	**-1.5**	**+2.8**
All Teams Avg Imp (T0-T9)			**+1.9 ➔ (1.9/20)x100 = +09.5%**									
Chapter 5	**SRS_1**	E1	12.5	10.0	13.5	12.5	10.5	13.5	12.5	08.0	14.0	11.5
		E2	13.5	13.0	11.5	12.0	10.0	13.0	11.0	09.0	13.5	12.5
		Avg1	**13.0**	**11.5**	**12.5**	**12.2**	**10.2**	**13.2**	**11.8**	**08.5**	**13.8**	**12.0**
	SRS_2	E1	16.5	10.0	14.5	15.0	12.0	10.0	18.0	11.5	12.0	13.5
		E2	19.5	17.0	14.0	16.5	16.5	15.0	18.5	12.5	15.0	13.5
		Avg2	**18.0**	**13.5**	**14.2**	**15.8**	**14.2**	**12.5**	**18.2**	**12.0**	**13.5**	**13.5**
Imp (Avg2-Avg1)			**+5.0**	**+2.0**	**+1.7**	**+3.6**	**+4.0**	**-0.7**	**+6.4**	**+3.5**	**-0.3**	**+1.5**
All Teams Avg Imp (T0-T9)			**+2.7 ➔ (2.7/20)x100 = +13.5%**									

Figure-5.7 Pilot Study, SRS Results (Team-wise, Chapters Improvements)

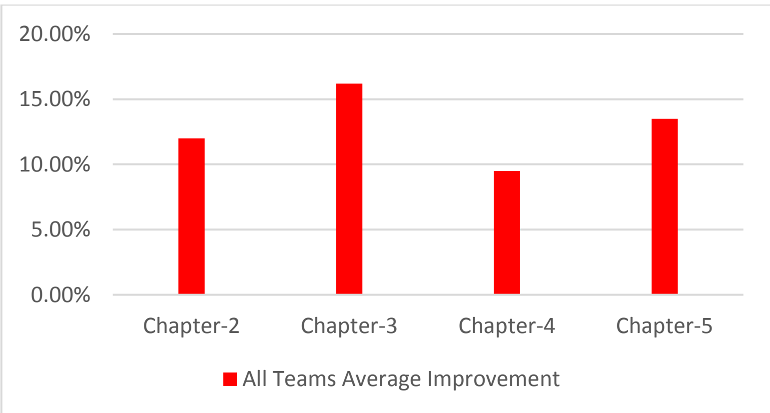

Figure -5.8 Pilot Study, SRS Results (Chapter-wise, Average Improvements)

Consider the table-5.7A, which has been used to show the results of evaluations of all pilot study teams in form of IEEE quality attribute-wise results sheet. This table shows an overall improvement gained of each of IEEE quality attributes of correctness, completeness, consistency and ranking/prioritization, which represent the overall system understandability aspects. This table shows the details of improvements gained by each team in these four quality attributes throughout the whole SRS chapters (chapter-1 to chapter-5). The overall results of this table have also been shown in figure-5.9A as a graph.

Table-5.7A Pilot Study, SRS Results (System Understandability Attributes Wise)

IEEE QC Attribute	Chapter (SRS)		T0	T1	T2	T3	T4	T5	T6	T7	T8	T9
IEEE QC-1 Correct (M=12.5)	**Chapter 2**	**SRS1**	1.75	1.75	1.75	2.00	2.00	1.75	1.75	1.75	1.75	2.00
		SRS2	2.50	2.50	2.25	2.50	2.50	2.25	2.25	2.25	2.50	2.50
		Imp	**0.75**	**0.75**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.75**	**0.50**
	Chapter 3	**SRS1**	3.00	4.00	3.00	2.75	3.75	2.50	3.25	3.00	4.00	2.50
		SRS2	4.25	5.00	4.75	4.75	4.75	4.00	4.75	4.75	4.75	5.00
		Imp	**1.25**	**1.00**	**1.75**	**2.00**	**1.00**	**1.50**	**1.50**	**1.75**	**0.75**	**2.50**
	Chapter 4	**SRS1**	1.25	1.00	1.25	1.50	1.25	1.50	2.00	1.50	1.75	1.25
Where		**SRS2**	2.00	2.50	2.25	2.50	2.25	2.25	2.25	2.25	2.25	2.00
		Imp	**0.75**	**1.50**	**1.00**	**1.00**	**1.00**	**0.75**	**0.25**	**0.75**	**0.50**	**0.75**
SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	1.50	1.50	2.00	2.25	1.25	1.25	1.50	0.75	1.75	1.25
		SRS2	2.50	2.25	2.25	2.50	2.50	2.00	2.50	1.50	2.25	2.25
		Imp	**1.00**	**0.75**	**0.25**	**0.25**	**1.25**	**0.75**	**1.00**	**0.75**	**0.50**	**1.00**
SRS2 (E1+E2)/2	**All Chapters Net Imp**		**3.75**	**4.00**	**3.50**	**3.75**	**3.75**	**3.50**	**3.25**	**3.75**	**2.50**	**4.75**
	Imp%		**30%**	**32%**	**28%**	**30%**	**30%**	**28%**	**26%**	**30%**	**20%**	**38%**
IEEE QC-3 Complete (M=12.5)	**Chapter 2**	**SRS1**	2.25	2.00	1.75	1.75	2.00	1.75	1.75	1.25	2.00	1.75
		SRS2	2.50	2.25	2.25	2.50	2.50	2.25	2.25	2.50	2.50	2.50
		Imp	**0.25**	**0.25**	**0.50**	**0.75**	**0.50**	**0.50**	**0.50**	**1.25**	**0.50**	**0.75**
	Chapter 3	**SRS1**	2.75	3.75	3.00	2.50	4.00	2.75	3.25	2.75	4.00	2.25
		SRS2	4.00	5.00	5.00	4.75	4.75	3.75	4.75	4.00	4.25	4.50
		Imp	**1.25**	**1.25**	**2.00**	**2.25**	**0.75**	**1.00**	**1.50**	**1.25**	**0.25**	**2.25**
	Chapter 4	**SRS1**	1.25	1.50	2.00	1.50	1.25	1.50	2.00	1.50	2.00	1.25
Where		**SRS2**	1.75	2.00	2.50	2.25	2.25	2.25	2.25	2.25	1.75	2.00

SRS1 (E1+E2)/2 SRS2 (E1+E2)/2		**Imp**	**0.50**	**0.50**	**0.50**	**0.75**	**1.00**	**0.75**	**0.25**	**0.75**	**-0.25**	**0.75**
	Chapter 5	**SRS1**	1.50	1.50	1.25	1.50	1.25	1.25	2.00	0.75	1.75	1.25
		SRS2	2.50	2.00	2.25	2.50	2.50	2.25	2.50	1.25	2.50	2.50
		Imp	**1.00**	**0.50**	**1.00**	**1.00**	**1.25**	**1.00**	**0.50**	**0.50**	**0.75**	**1.25**
	All Chapters Net Imp		**3.00**	**2.50**	**4.00**	**4.75**	**3.50**	**3.25**	**2.75**	**3.75**	**1.25**	**5.00**
	Imp%		**24%**	**20%**	**32%**	**38%**	**28%**	**26%**	**22%**	**30%**	**10%**	**40%**
IEEE QC-4 Consistent (M=12.5) Where SRS1 (E1+E2)/2 SRS2 (E1+E2)/2	**Chapter 2**	**SRS1**	2.00	1.75	1.75	1.75	2.25	1.50	1.75	1.50	1.75	1.75
		SRS2	2.50	2.25	2.25	2.25	2.25	1.50	2.25	2.50	2.25	2.25
		Imp	**0.50**	**0.50**	**0.50**	**0.50**	**0.00**	**0.00**	**0.50**	**1.00**	**0.50**	**0.50**
	Chapter 3	**SRS1**	3.00	2.75	3.25	2.50	3.25	3.00	3.50	2.75	3.75	2.25
		SRS2	4.25	4.25	4.00	4.00	4.50	3.25	4.25	4.25	3.00	4.25
		Imp	**1.25**	**1.50**	**0.75**	**1.50**	**1.25**	**0.25**	**0.75**	**1.50**	**-0.75**	**2.00**
	Chapter 4	**SRS1**	1.50	1.50	1.25	1.50	1.25	2.00	1.75	2.00	2.25	1.25
		SRS2	1.25	1.75	2.00	2.25	2.25	1.25	2.00	2.00	2.00	2.00
		Imp	**-0.25**	**0.25**	**0.75**	**0.75**	**1.00**	**-0.75**	**0.25**	**0.00**	**-0.25**	**0.75**
	Chapter 5	**SRS1**	2.00	1.50	1.50	1.75	1.00	2.00	1.75	1.50	1.75	1.75
		SRS2	2.25	2.00	1.75	2.00	1.75	1.75	2.50	1.75	1.50	2.00
		Imp	**0.25**	**0.50**	**0.25**	**0.25**	**0.75**	**-0.25**	**0.75**	**0.25**	**-0.25**	**0.25**
	All Chapters Net Imp		**1.75**	**2.75**	**2.25**	**3.00**	**3.00**	**-0.75**	**2.25**	**2.75**	**-0.75**	**3.50**
	Imp%		**14%**	**22%**	**18%**	**24%**	**24%**	**-06%**	**18%**	**22%**	**-06%**	**28%**
IEEE QC-5 Ranked (M=12.5) Where SRS1 (E1+E2)/2 SRS2 (E1+E2)/2	**Chapter 2**	**SRS1**	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
		SRS2	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
		Imp	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Chapter 3	**SRS1**	2.00	3.25	3.00	3.00	0.00	2.25	3.75	0.00	1.75	1.25
		SRS2	2.25	4.25	3.75	4.50	1.50	2.75	3.75	3.50	1.75	2.00
		Imp	**0.25**	**1.00**	**0.75**	**1.50**	**1.50**	**0.50**	**0.00**	**3.50**	**0.00**	**0.75**
	Chapter 4	**SRS1**	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
		SRS2	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A
		Imp	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Chapter 5	**SRS1**	0.75	1.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
		SRS2	1.75	0.75	0.00	1.00	0.00	0.00	1.50	0.00	0.50	0.00
		Imp	**1.00**	**-0.25**	**0.00**	**0.50**	**0.00**	**0.00**	**1.50**	**0.00**	**0.50**	**0.00**
	All Chapters Net Imp		**1.25**	**0.75**	**0.75**	**2.00**	**1.50**	**0.50**	**1.50**	**3.50**	**0.50**	**0.75**
	Imp%		**10%**	**06%**	**06%**	**16%**	**12%**	**04%**	**12%**	**28%**	**04%**	**06%**

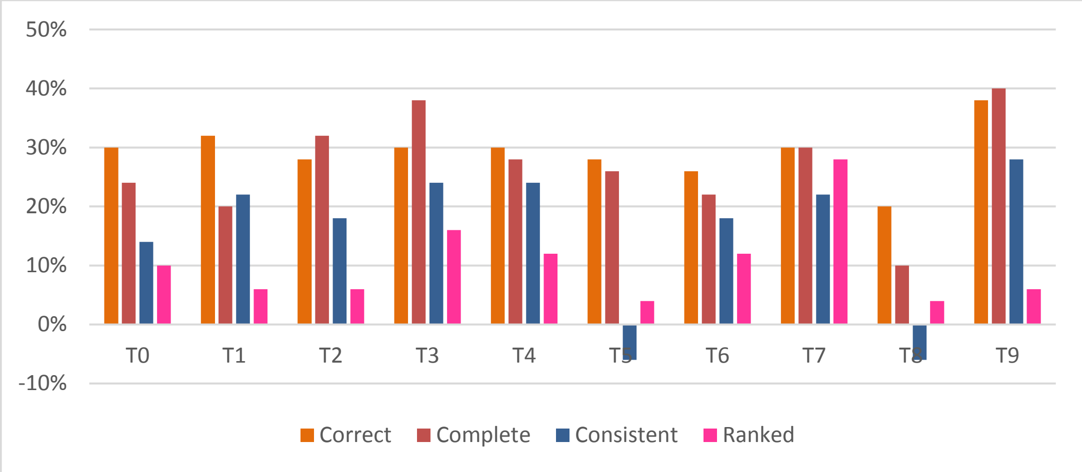

Figure-5.9A Pilot Study, SRS Results (Team-wise, Attributes Improvements)

Consider the table-5.7B, which has been used to show the results of evaluations of all pilot study teams in form of IEEE quality attribute-wise results sheet. This table shows an overall improvement gained of each of IEEE quality attributes of unambiguousness, verifiability, modifiability and traceability, which represent the overall requirements writing aspects. This table shows the details of improvements gained by each team in these four quality attributes throughout the whole SRS chapters. The overall results of this table have also been shown in figure-5.9B as a graph.

Table-5.7B Pilot Study, SRS Results (Requirements Writing Attributes Wise)

IEEE QC Attribute	**Chapter (SRS)**		**T0**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**
IEEE QC-2 Unambiguous (M=12.5)	**Chapter 2**	**SRS1**	2.25	1.75	1.75	1.50	2.00	2.00	2.00	1.50	2.00	2.00
		SRS2	2.50	2.25	2.25	1.75	1.75	1.50	1.75	1.50	2.25	2.50
		Imp	**0.25**	**0.50**	**0.50**	**0.25**	**-0.25**	**-0.50**	**-0.25**	**0.00**	**0.25**	**0.50**
	Chapter 3	**SRS1**	2.75	3.50	2.75	2.50	3.75	3.25	3.00	2.75	4.00	1.75
		SRS2	3.75	4.50	3.00	3.25	4.25	2.75	4.00	2.75	3.00	2.75
		Imp	**1.00**	**1.00**	**0.25**	**0.75**	**0.50**	**-0.50**	**1.00**	**0.00**	**-1.00**	**1.00**
Where	**Chapter 4**	**SRS1**	1.25	1.75	1.75	1.50	1.75	1.50	2.00	1.50	1.75	1.00
		SRS2	1.50	2.00	1.75	1.25	2.00	1.50	2.00	1.25	1.75	1.25
		Imp	**0.25**	**0.25**	**0.00**	**-0.25**	**0.25**	**0.00**	**0.00**	**-0.25**	**0.00**	**0.25**

SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	1.50	1.00	2.00	1.50	1.50	1.75	1.75	1.00	2.25	1.75
		SRS2	2.50	1.50	2.25	1.75	1.50	1.50	2.25	1.50	1.75	1.75
SRS2 (E1+E2)/2		**Imp**	**1.00**	**0.50**	**0.25**	**0.25**	**0.00**	**-0.25**	**0.50**	**0.50**	**-0.50**	**0.00**
	All Chapters Net Imp		**2.50**	**2.25**	**1.00**	**1.00**	**0.50**	**-1.25**	**1.25**	**0.25**	**-1.25**	**1.75**
	Imp%		**20%**	**18%**	**08%**	**08%**	**04%**	**-10%**	**10%**	**02%**	**-10%**	**14%**
IEEE QC-6 Verifiable (M=12.5)	**Chapter 2**	**SRS1**	2.00	1.75	2.00	1.00	2.00	1.50	1.75	1.25	1.25	2.00
		SRS2	2.50	2.25	2.50	1.75	2.25	1.50	2.50	1.50	2.50	1.75
		Imp	**0.50**	**0.50**	**0.50**	**0.75**	**0.25**	**0.00**	**0.75**	**0.25**	**1.25**	**-0.25**
	Chapter 3	**SRS1**	3.00	3.25	3.00	2.50	2.50	3.50	3.25	2.00	3.75	2.75
		SRS2	3.50	4.25	3.75	3.25	3.75	3.50	4.00	2.50	3.25	3.50
		Imp	**0.50**	**1.00**	**0.75**	**0.75**	**1.25**	**0.00**	**0.75**	**0.50**	**-0.50**	**0.75**
	Chapter 4	**SRS1**	1.50	1.75	1.75	1.75	1.50	1.75	1.50	1.25	2.00	1.25
Where		**SRS2**	1.50	1.25	2.25	1.50	1.75	1.25	2.00	1.75	1.50	1.75
		Imp	**0.00**	**-0.50**	**0.50**	**-0.25**	**0.25**	**-0.50**	**0.50**	**0.50**	**-0.50**	**0.50**
SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	1.75	1.50	1.25	1.50	1.00	2.25	1.25	1.25	1.75	2.00
		SRS2	2.00	1.50	1.75	2.00	1.50	1.50	2.00	2.00	1.75	1.50
		Imp	**0.25**	**0.00**	**0.50**	**0.50**	**0.50**	**-0.75**	**0.75**	**0.75**	**0.00**	**-0.50**
SRS2 (E1+E2)/2	**All Chapters Net Imp**		**1.25**	**1.00**	**2.25**	**1.75**	**2.25**	**-1.25**	**2.75**	**2.00**	**0.25**	**0.50**
	Imp%		**10%**	**08%**	**18%**	**14%**	**18%**	**-10%**	**22%**	**16%**	**02%**	**04%**
IEEE QC-7 Modifiable (M=12.5)	**Chapter 2**	**SRS1**	2.25	2.25	2.25	2.50	2.25	2.25	2.50	1.75	2.00	2.25
		SRS2	2.50	2.25	2.25	2.50	2.25	2.50	2.25	1.75	2.25	2.25
		Imp	**0.25**	**0.00**	**0.00**	**0.00**	**0.00**	**0.25**	**-0.25**	**0.00**	**0.25**	**0.00**
	Chapter 3	**SRS1**	4.00	3.50	3.75	3.50	3.50	4.00	4.50	3.00	4.00	3.75
		SRS2	4.50	4.00	4.25	4.00	4.75	4.00	4.50	3.00	3.75	3.50
		Imp	**0.50**	**0.50**	**0.50**	**0.50**	**1.25**	**0.00**	**0.00**	**0.00**	**-0.25**	**-0.25**
	Chapter 4	**SRS1**	1.75	2.25	1.75	1.75	1.75	2.25	1.75	2.00	2.25	2.25
Where		**SRS2**	1.50	2.25	2.25	2.00	2.50	1.75	2.50	2.00	1.75	1.75
		Imp	**-0.25**	**0.00**	**0.50**	**0.25**	**0.75**	**-0.50**	**0.75**	**0.00**	**-0.50**	**-0.50**
SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	2.00	1.75	2.25	1.75	2.25	2.25	1.75	1.75	2.25	2.00
		SRS2	2.25	1.75	1.75	2.00	2.25	1.75	2.50	2.00	1.50	1.75
		Imp	**0.25**	**0.00**	**-0.50**	**0.25**	**0.00**	**-0.50**	**0.75**	**0.25**	**-0.75**	**-0.25**
SRS2 (E1+E2)/2	**All Chapters Net Imp**		**0.75**	**0.50**	**0.50**	**1.00**	**2.00**	**-0.75**	**1.25**	**0.25**	**-1.25**	**-1.00**
	Imp%		**06%**	**04%**	**04%**	**08%**	**16%**	**-06%**	**10%**	**02%**	**-10%**	**-08%**
IEEE QC-8 Traceable (M=12.5)	**Chapter 2**	**SRS1**	2.25	2.00	2.00	1.75	2.50	2.00	2.50	2.25	2.00	2.25
		SRS2	2.25	2.00	2.50	2.50	2.25	1.75	2.50	1.75	2.25	2.50
		Imp	**0.00**	**0.00**	**0.50**	**0.75**	**-0.25**	**-0.25**	**0.00**	**-0.50**	**0.25**	**0.25**
	Chapter 3	**SRS1**	4.00	3.50	3.50	3.50	3.50	4.00	4.75	3.00	3.50	4.25
		SRS2	4.50	4.00	3.75	4.50	4.75	4.00	4.75	3.00	3.75	4.50
		Imp	**0.50**	**0.50**	**0.25**	**1.00**	**1.25**	**0.00**	**0.00**	**0.00**	**0.25**	**0.25**
	Chapter	**SRS1**	1.50	1.75	4.00	2.00	2.00	2.00	2.00	2.00	2.50	1.75

Where SRS1 (E1+E2)/2 SRS2 (E1+E2)/2	**4**	**SRS2**	2.00	1.75	2.25	2.50	2.50	1.50	2.00	2.25	2.00	2.00
		Imp	**0.50**	**0.00**	**-1.75**	**0.50**	**0.50**	**-0.50**	**0.00**	**0.25**	**-0.50**	**0.25**
	Chapter 5	**SRS1**	2.00	1.75	2.25	1.50	2.00	2.50	1.75	1.50	2.25	2.00
		SRS2	2.25	1.75	2.25	2.00	2.25	1.75	2.50	2.00	1.75	1.75
		Imp	**0.25**	**0.00**	**0.00**	**0.50**	**0.25**	**-0.75**	**0.75**	**0.50**	**-0.50**	**-0.25**
	All Chapters Net Imp		**1.25**	**0.50**	**-1.00**	**2.75**	**1.75**	**-1.50**	**0.75**	**0.25**	**-0.50**	**0.50**
	Imp%		**10%**	**04%**	**-08%**	**22%**	**14%**	**-12%**	**06%**	**02%**	**-04%**	**04%**

Figure-5.9B Pilot Study, SRS Results (Team-wise, Attributes Improvements)

Consider the table-5.8, which has been used to show the results of evaluations of all pilot study teams in form of IEEE quality attribute-wise complete results sheet. This table shows an overall improvement gained of each of IEEE quality attributes of correctness, completeness, consistency, ranking, unambiguousness, verifiability, modifiability and traceability. This table shows the details of improvements gained by each team in all these quality attributes throughout the whole SRS chapters (chapter-1 to chapter-5). The table also shows the average improvement of all teams in each quality attribute. The overall results of this table have also been shown in figure-5.10 as a pi-chart graph.

Table-5.8 Pilot Study, SRS Results (Attributes Wise)

	IEEE QC Attribute	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	All Teams Avg Imp
System Understanding Attributes	**System Scope Understandability**											
	IEEE QC-1 Correct	30%	32%	28%	30%	30%	28%	26%	30%	20%	38%	**29.2%**
	IEEE QC-3 Complete	24%	20%	32%	38%	28%	26%	22%	30%	10%	40%	**27.0%**
	System Feature Understandability											
	IEEE QC-4 Consistent	14%	22%	18%	24%	24%	-06%	18%	22%	-06%	28%	**15.8%**
	IEEE QC-5 Ranked	10%	06%	06%	16%	12%	04%	12%	28%	04%	06%	**10.4%**
Requirements Writing Attributes	**Requirements Writing Styles**											
	IEEE QC-2 Unambiguous	20%	18%	08%	08%	04%	-10%	10%	02%	-10%	14%	**06.4%**
	IEEE QC-6 Verifiable	10%	08%	18%	14%	18%	-10%	22%	16%	02%	04%	**10.2%**
	Requirements Writing Structures											
	IEEE QC-7 Modifiable	06%	04%	04%	08%	16%	-06%	10%	02%	-10%	-08%	**02.6%**
	IEEE QC-8 Traceable	10%	04%	-08%	22%	14%	-12%	06%	02%	-04%	04%	**03.8%**
All Teams Avg SRS Imp = 13.2%												
13.4% - 13.2% = 0.2% Round Off Error												

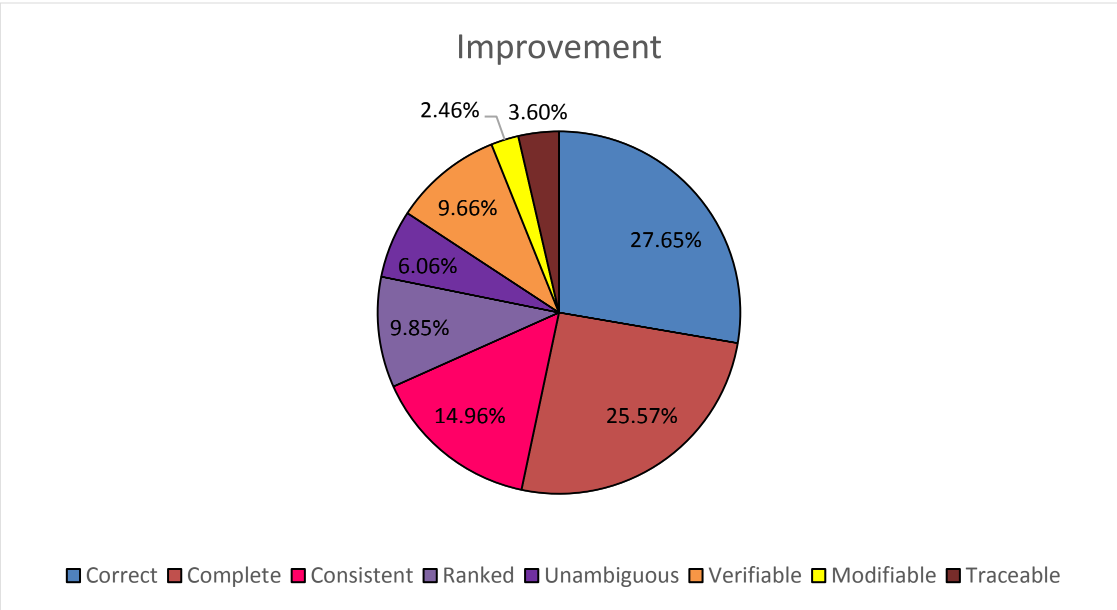

Figure-5.10 Pilot Study, SRS Results (Attributes Wise Improvement)

5.2 FRAMEWORK INDUSTRIAL EVALUATION (REAL STUDY)

The industrial study of the proposed framework was carried-out in three different software development companies including Software Company SC-1 (Android Games Development Company), Software Company SC-2 (Android Apps Development Company) and Software Company SC-3 (Web Development Company). The software company SC-1 was based on low geographical distribution in its requirements elicitation team where analyst-team was distributed in single country and user-team was distributed in single country. The software company SC-2 was based on medium geographical distribution in its requirements elicitation team where analyst-team was distributed in two different countries and user-team was distributed in single country. The software company SC-3 was based on high geographical distribution in its requirements elicitation team where analyst-team was distributed in two different countries and user-team was distributed in two different countries.

The selected software development companies were purely working in global software development context and were engaged in three different types of projects including android game development project, android apps development project and web development project. All three companies were asked to compose two different requirements elicitation teams with equal sizes and equal resources. The first requirements elicitation team was asked to do the requirements elicitation process for their assigned project without using the proposed framework and document the elicited requirements using IEEE SRS standard. The second requirements elicitation team was asked to do the requirements elicitation process for their assigned project with using proposed framework and document the elicited requirements using IEEE SRS standard. Afterwards, the results of both SRS were compared to see the impact of proposed framework on the requirements elicitation process for global software development projects.

5.2.1 Industrial Study, Sample Characteristics

Consider the given table-5.9, which shows the main characteristics of the selected sample chosen from population for the industrial evaluation (real study) of the proposed framework. The mentioned sample has been taken from a population of different offshore software development companies operating in Pakistan.

Table 5.9 Sample Characteristics in Industrial Evaluation

Sr#	Parameter	Characteristics
1.	Sample Type	Software Development Companies
2.	Sample Category	Offshore Software Companies
3.	Sample Projects	Web, Android Games and Apps Development
4.	Sample Size (Total Companies)	Three Companies of Moderate Sizes
5.	Sample Structure (RE Team Distribution)	Low, Medium, High
6.	Sample Gender Type	Mixed (Male & Female)
7.	Sample Age Groups	25 Years To 55 Years
8.	Sample Geographical Distribution	Globally Variant (True Offshore Scenario)
9.	Sample Culture Diversity	Globally Variant (True Offshore Scenario)
10.	Sample Temporal Dispersion	Globally Variant (True Offshore Scenario)
11.	Sample Linguistic Diversity	Globally Variant (True Offshore Scenario)
12.	Involved Professionals Working Experience	05 Years to 25 Years

5.2.2 Industrial Study, Experiment Characteristics

Consider the given table-5.10, which shows the characteristics of the experiment conducted during the industrial evaluation (real study) of the proposed framework. As described already, the presented industrial experiment was performed on three different offshore software development companies.

Table-5.10 Industrial Study, Experiment Characteristics

Sr#	Parameters	Values/Characteristics
1.	Experiment Overall Duration	About Three Months
2.	Experiment Projects Complexity	Medium-to-High Level Complexity
3.	Experiment Projects Domain	Project-1 (Games), Project-2 (Apps) & Project-3 (Web)
4.	Experiment Projects Tasks	Requirements Elicitation and Specifications
5.	Experiment SRS Standard Used	IEEE SRS Standard Std. 830-1998 (R2009)
6.	Experiment Evaluators Involved	Two Company Internal Evaluators
7.	Experiment Evaluator Profiles	One Team Head One Team Member
8.	Experiment Evaluation Tool	Six Data Collection Forms Six Data Analysis Forms
9.	Experiment Personality Model Used	Big-Five Personality Assessment Model
10.	Experiment Personality Traits Standard Used	NEO-IPIP 50 Items Inventory Used

5.2.3 Industrial Study, Scenario Characteristics

The selected software development companies were of small-to-medium size with low, medium and high geographical distribution in their requirements elicitation teams. The Pakistan was taken as a base-country for the industrial study and therefore the term Country-1 is representing the base-country i.e. Pakistan. The structural details of low, medium and high geographical distribution in the requirements elicitation teams is explained in following paragraph.

- **RE Team with Low Geographical Distribution**

Analyst Team = Single Country (Country-1)

User Team = Single Country (Country-2)

- **RE Team with Medium Geographical Distribution**

Analyst Team = Single Country (Country-1)

User Team = Multiple Countries (Country-1, Country-2, Country-3 … Country-N)

OR

Analyst Team = Multiple Countries (Country-1, Country-2, Country-3 … Country-N)

User Team = Single Country (Country-1/Country-2/Country-3 … /Country-N)

- **RE Team with High Geographical Distribution**

Analyst Team = Multiple Countries (Country-1, Country-2, Country-3 … Country-N)

User Team = Multiple Countries (Country-1, Country-2, Country-3 … Country-N)

5.2.4 Industrial Study, Results Analysis

In first-group of the industrial study, the requirements elicitation teams of each software company (SC-1, SC-2 and SC-3) were asked to perform requirements elicitations process without using proposed framework and document the elicited requirements of the assigned product/project using IEEE SRS standard. In second-group of the industrial study, the requirements elicitation teams were asked to use the proposed framework for requirements elicitation process and document the elicited requirements using the same

IEEE standard. In this way, each software company documented two SRS including SRS-1 made without using proposed framework and SRS-2 made with using the proposed framework.

The expert judgment methodology was used to evaluate the both SRS documents developed by each software company. Accordingly, both SRS of each software company were given to same company for internal evaluation by team head and one team member for numerical grading to transform the qualitative data into quantitative data for further analysis. The chosen experts were asked to grade each SRS on basis of 100 marks that were equally distributed among eight quality attributes of IEEE SRS standard Std. 830 (R2009). Each SRS was internally graded as chapter wise and as IEEE quality attributes wise to more precisely judge the outcomes of the requirements elicitation process.

Consider the given table-5.11, which has been used to show the details of the grades assigned by both evaluators to both SRS of each company. The table shows the company improvements gained during SRS-2 development as compared to SRS-1 development and all companies' average improvements for both evaluators. The table also shows all companies overall improvements by using proposed framework for requirements elicitations. A total of 9.2% quality improvement (in terms of IEEE defined eight quality attributes of SRS) in requirements elicitation process was observed during the industrial study based on the use of proposed framework for requirements elicitations.

Table-5.11 Industrial Study, Overall Results (Evaluators Wise)

Industrial Study Overall Results Comparison				
Software Company	**SRS1 Results** (Without Framework)	**SRS2 Results** (With Framework)	**Company Improve**	**Average Improve**
Evaluator-1 (Developer Company, Head) Results				
SC-1 (Game Dev)	65.0	74.0	+09.0	**+11.0**
SC-2 (App Dev)	60.0	73.0	+13.0	
SC-3 (Web Dev)	59.5	70.5	+11.0	
Evaluator-2 (Developer Company, Member) Results				
SC-1 (Game Dev)	77.5	85.0	+07.5	**+07.5**
SC-2 (App Dev)	53.0	61.5	+08.5	
SC-3 (Web Dev)	61.5	68.0	+06.5	
All Companies Overall Average Improvement				**+09.2%**

Consider the given table-5.12A, which has been used to show the results of evaluations of SRS-1 and SRS-2 of each software company by both evaluators (team head as evaluator-1 and one team member as evaluator-2). An average value of SRS-1 and SRS-2 have been taken from results of both evaluators to minimize the evaluator’s biasness effect. The table shows the overall average of all companies’ grades of both SRS and calculates the overall improvements by all companies during the industrial study using proposed framework. The results of this table have also been shown as a graph in figure-5.11. Also, the given table-5.12B provides the detailed statistical analysis of data obtained from whole data set of all companies to calculate mean value, median value, mode value and standard deviation value.

Table-5.12A Industrial Study, Overall Results (Companies SRS Wise)

SRS	Evaluator	SC-1 (Game Dev)	SC-2 (App Dev)	SC-3 (Web Dev)
SRS1	Evaluator-1	65.0	60.0	59.5
	Evaluator-2	77.5	53.0	61.5
	Avg (E1+E2)/2	71.25	56.50	60.50
	All Companies Avg (Avg1)	62.8%		
SRS2	Evaluator-1	74.0	73.0	70.5
	Evaluator-2	85.0	61.5	68.0
	Avg (E1+E2)/2	79.50	67.25	69.25
	All Companies Avg (Avg2)	72.0%		
All Companies Individual Imp		+08.25	+10.75	+08.75
Overall Imp (Avg2-Avg1)		+09.2%		

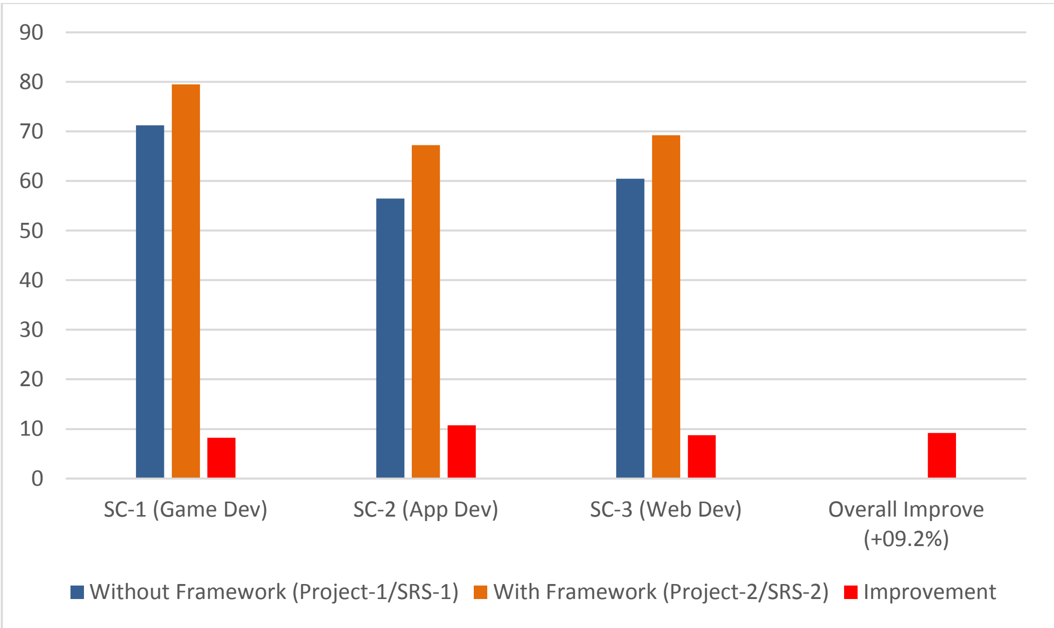

Figure-5.11 Industrial Study, Overall Results (Company-wise, SRS Improvements)

Table-5.12B Industrial Study, Statistical Analysis of Overall Results

SRS	Evaluator	SC-1 (Game Dev)	SC-2 (App Dev)	SC-3 (Web Dev)
SRS1	Evaluator-1	65.0	60.0	59.5
	Evaluator-2	77.5	53.0	61.5
	Avg1 (E1+E2)/2	71.25	56.50	60.50
SRS2	Evaluator-1	74.0	73.0	70.5
	Evaluator-2	85.0	61.5	68.0
	Avg2 (E1+E2)/2	79.50	67.25	69.25
All Teams Individual Imp		08.25	10.75	08.75
Mean, Median, Mode, Standard Deviation				
Ascending Sorted Values		08.25	08.75	10.75
		SC-1	SC-3	SC-2
Mean Value		09.25		
Median Value		**08.75**		
Mode Value		**08.75**		
Standard Deviation		**01.32**		

Consider the table-5.13, which has been used to show the results of evaluations of all software companies in form of chapter-wise results sheet. This table shows an overall improvement gained of 6.65% in chapter-2, 11.45% in chapter-3, 15.4% in chapter-4 and 1.25% in chapter-5 of the SRS by all companies of industrial study. This chapter is concerned with the overall system descriptions and hence, relates to overall system understandability. Therefore, improvement gained in this chapter is a direct reflection of stakeholder's system understandability developed during requirements elicitation process using proposed framework. The company-wise improvements results of this table have been shown in figure-5.12, while chapter-wise improvements results of this table have been shown in figure-5.13.

Table-5.13 Industrial Study, SRS Results (Chapter Wise)

Chapter	SRS (Evaluator)		SC-1 (Game Dev)	SC-2 (App Dev)	SC-3 (Web Dev)
Chapter 2	SRS_1	E1	12.0	13.5	10.0
		E2	14.0	12.0	14.0
		Avg1	**13.00**	**12.75**	**12.00**
	SRS_2	E1	14.5	13.0	13.0
		E2	17.0	15.0	11.0
		Avg2	**15.75**	**14.00**	**12.00**
Imp (Avg2-Avg1)			**+2.75**	**+1.25**	**0.00**
All Companies Avg Imp			**+1.33 ➔ (1.33/20) x 100 = +6.65%**		
Chapter 3	SRS_1	E1	29.5	24.0	23.5
		E2	33.5	24.0	24.0
		Avg1	**31.50**	**24.00**	**23.75**
	SRS_2	E1	31.0	30.0	32.0
		E2	36.0	25.0	32.0
		Avg2	**33.50**	**27.50**	**32.00**
Imp (Avg2-Avg1)			**+2.00**	**+3.50**	**+8.25**
All Companies Avg Imp			**+4.58 ➔ (4.58/40) x 100 = +11.45%**		
Chapter 4	SRS_1	E1	12.5	11.0	13.0
		E2	15.0	09.0	11.5
		Avg1	**13.75**	**10.00**	**12.25**
	SRS_2	E1	16.0	17.0	15.5
		E2	14.5	13.0	14.5
		Avg2	**15.25**	**15.00**	**15.00**
Imp (Avg2-Avg1)			**+1.50**	**+5.00**	**+2.75**
All Companies Avg Imp			**+3.08 ➔ (3.08/20) x 100 = +15.4%**		
Chapter 5	SRS_1	E1	11.0	11.5	13.0
		E2	15.0	08.0	12.0
		Avg1	**13.00**	**09.75**	**12.50**
	SRS_2	E1	12.5	13.0	10.0
		E2	17.5	08.5	10.5
		Avg2	**15.00**	**10.75**	**10.25**
Imp (Avg2-Avg1)			**+2.00**	**+1.00**	**-2.25**
All Companies Avg Imp			**+0.25 ➔ (0.25/20) x 100 = +1.25%**		

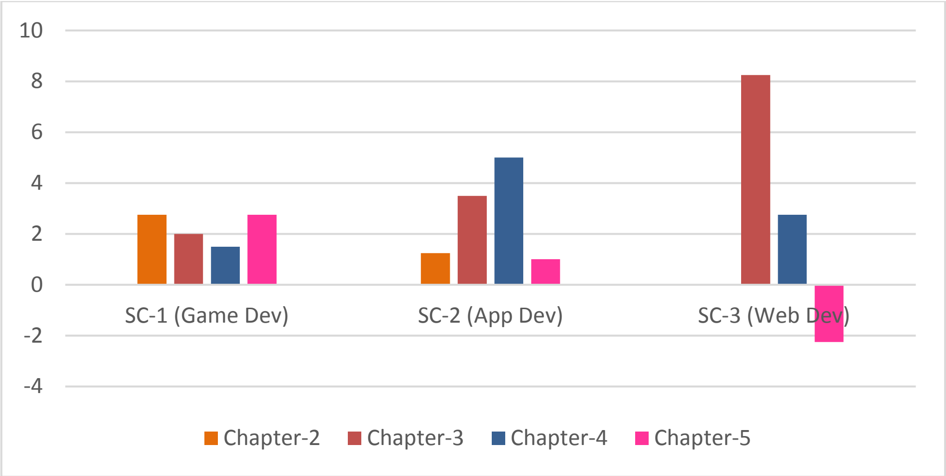

Figure-5.12 Industrial Study, SRS Results (Company-wise, Chapter Improvement)

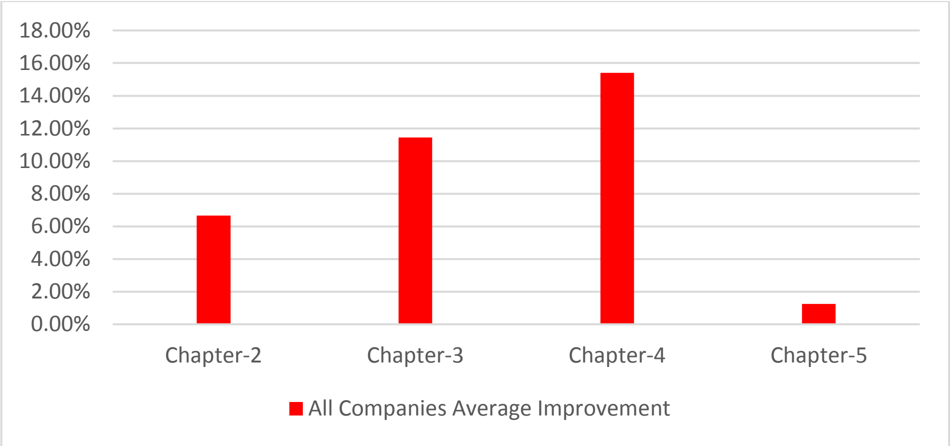

Figure-5.13 Industrial Study SRS Results (Chapter-wise, Average Improvement)

Consider the table-5.14A, which has been used to show the results of evaluations of all industrial study companies in form of IEEE quality attribute-wise results sheet. This table shows an overall improvement gained of each of IEEE quality attributes of correctness, completeness, consistency and ranking, which represent the overall system understandability aspects. This table shows the details of improvements gained by each software company in these four quality attributes throughout the whole SRS chapters (chapter-1 to chapter-5). The overall results of this table have also been shown in figure-5.14A as a graph.

Table-5.14A Industrial Study, SRS Results (System Understandability Wise)

IEEE QC Attribute	Chapter (SRS)		SC-1 (Game Dev)	SC-2 (App Dev)	SC-3 (Web Dev)
IEEE QC-1 Correct (M=12.5)	**Chapter 2**	**SRS1**	1.50	2.25	2.00
		SRS2	2.50	2.25	2.00
		Imp	**1.00**	**0.00**	**0.00**
	Chapter 3	**SRS1**	3.00	2.25	3.00
		SRS2	4.75	4.25	4.50
		Imp	**1.75**	**2.00**	**1.50**
Where	**Chapter 4**	**SRS1**	1.50	1.25	1.25
		SRS2	2.25	2.50	2.50
		Imp	**0.75**	**1.25**	**1.25**
SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	1.25	1.00	1.00
		SRS2	2.25	2.00	2.00
		Imp	**1.00**	**1.00**	**1.00**
SRS2 (E1+E2)/2	**All Chapters Net Imp**		**+4.50**	**+4.50**	**+3.75**
	Imp%		**+36.0%**	**+36.0%**	**+30.0%**
IEEE QC-3 Complete (M=12.5)	**Chapter 2**	**SRS1**	1.50	1.75	2.25
		SRS2	2.50	2.50	1.75
		Imp	**1.00**	**0.75**	**-0.50**
	Chapter 3	**SRS1**	3.00	2.00	2.75
		SRS2	5.00	4.50	4.50
		Imp	**2.00**	**2.50**	**1.75**
Where	**Chapter 4**	**SRS1**	1.50	1.25	1.25
		SRS2	2.50	2.50	2.50
		Imp	**1.00**	**1.25**	**1.25**
SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	1.75	1.00	1.25
		SRS2	2.50	2.00	1.75
		Imp	**0.75**	**1.00**	**0.50**
SRS2 (E1+E2)/2	**All Chapters Net Imp**		**+4.75**	**+5.50**	**+3.00**
	Imp%		**+38.0%**	**+44.0%**	**+24.0%**
IEEE QC-4 Consistent (M=12.5)	**Chapter 2**	**SRS1**	1.75	1.75	1.25
		SRS2	2.25	1.75	1.50
		Imp	**0.50**	**0.00**	**0.25**
	Chapter 3	**SRS1**	3.25	2.25	2.25
		SRS2	4.25	4.50	3.75
		Imp	**1.00**	**2.25**	**1.50**
Where	**Chapter 4**	**SRS1**	1.50	1.00	1.50
		SRS2	2.00	2.25	2.50
		Imp	**0.50**	**1.25**	**1.00**

SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	1.25	1.00	1.75
		SRS2	2.25	1.50	1.50
SRS2 (E1+E2)/2		**Imp**	**1.00**	**0.50**	**-0.25**
	All Chapters Net Imp		**+3.00**	**+4.00**	**+2.50**
	Imp%		**+24.0%**	**+32.0%**	**+20.0%**
IEEE QC-5 Ranked (M=12.5)	**Chapter 2**	**SRS1**	N.A	N.A	N.A
		SRS2	N.A	N.A	N.A
		Imp	**0.00**	**0.00**	**0.00**
	Chapter 3	**SRS1**	4.25	4.00	0.50
		SRS2	1.75	0.00	4.50
		Imp	**-2.50**	**-4.00**	**4.00**
	Chapter 4	**SRS1**	N.A	N.A	N.A
		SRS2	N.A	N.A	N.A
Where		**Imp**	**0.00**	**0.00**	**0.00**
SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	1.25	0.00	0.00
		SRS2	0.75	0.00	0.00
SRS2 (E1+E2)/2		**Imp**	**-0.50**	**0.00**	**0.00**
	All Chapters Net Imp		**-3.00**	**-4.00**	**+4.00**
	Imp%		**-24.0%**	**-32.0%**	**+32.0%**

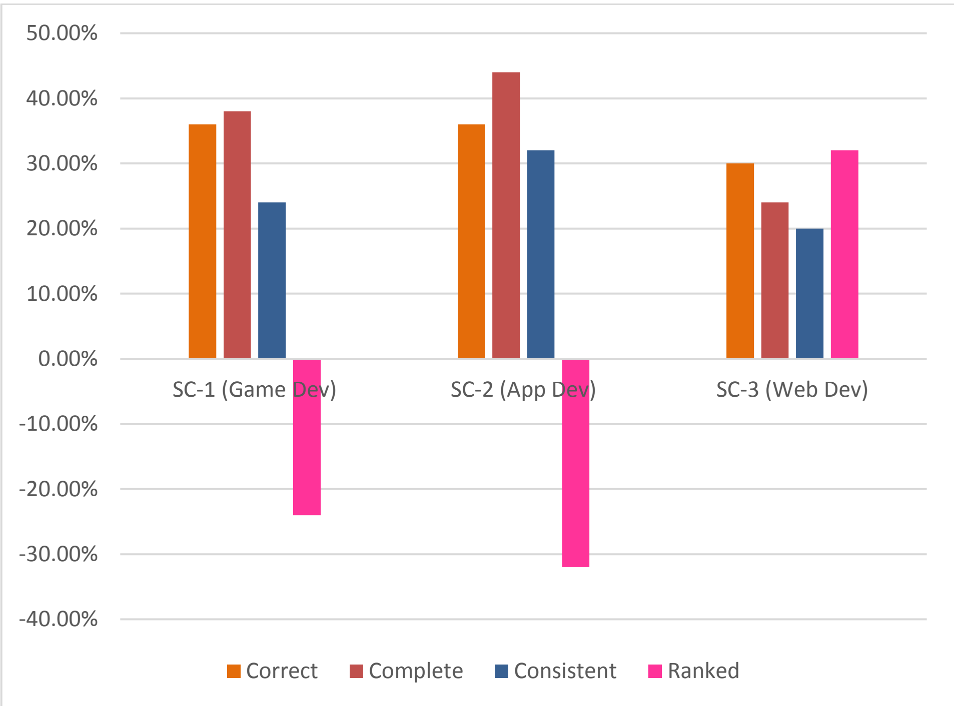

Figure-5.14A Industrial Study, SRS Results (Company-wise, Attributes Improvements)

Consider the table-5.14B, which has been used to show the results of evaluations of all industrial study companies in form of IEEE quality attribute-wise results sheet. This table shows an overall improvement gained of each of IEEE quality attributes of unambiguousness, verifiability, modifiability and traceability, which represent the overall requirements writing aspects. This table shows the details of improvements gained by each software company in these four quality attributes throughout the whole SRS chapters (chapter-1 to chapter-5). The overall results of this table have also been shown in figure-5.14B as a graph.

Table-5.14B Industrial Study, SRS Results (Requirements Writing Wise)

IEEE QC Attribute	Chapter (SRS)		SC-1 (Game Dev)	SC-2 (App Dev)	SC-3 (Web Dev)
IEEE QC-2 Unambiguous (M=12.5)	**Chapter 2**	**SRS1**	1.25	1.50	1.50
		SRS2	1.75	1.75	1.75
		Imp	**0.50**	**0.25**	**0.25**
	Chapter 3	**SRS1**	3.75	2.75	3.75
		SRS2	4.00	2.75	3.25
		Imp	**0.25**	**0.00**	**-0.50**
	Chapter 4	**SRS1**	2.00	1.25	2.00
Where		**SRS2**	1.75	1.75	2.00
		Imp	**-0.25**	**0.50**	**0.00**
SRS1 (E1+E2)/2	**Chapter 5**	**SRS1**	2.00	1.50	2.00
		SRS2	1.50	1.00	1.50
		Imp	**-0.50**	**-0.50**	**-0.50**
SRS2 (E1+E2)/2	**All Chapters Net Imp**		**0.00**	**+0.25**	**-0.75**
	Imp%		**00.0%**	**+02.0%**	**-06.0%**
IEEE QC-6 Verifiable (M=12.5)	**Chapter 2**	**SRS1**	2.25	1.75	1.75
		SRS2	2.00	1.75	1.75
		Imp	**-0.25**	**0.00**	**0.00**
	Chapter 3	**SRS1**	4.50	3.25	3.75
		SRS2	4.00	4.00	4.00
		Imp	**-0.50**	**0.75**	**0.25**
	Chapter 4	**SRS1**	2.25	1.50	2.00
Where		**SRS2**	2.25	1.75	1.50

SRS1 (E1+E2)/2 SRS2 (E1+E2)/2		**Imp**	**0.00**	**0.25**	**-0.50**
	Chapter 5	**SRS1**	1.75	1.75	2.25
		SRS2	2.00	1.00	1.25
		Imp	**0.25**	**-0.75**	**-1.00**
	All Chapters Net Imp		**-0.50**	**+0.25**	**-1.25**
	Imp%		**-04.0%**	**+02.0%**	**-10.0%**
IEEE QC-7 Modifiable (M=12.5) Where SRS1 (E1+E2)/2 SRS2 (E1+E2)/2	**Chapter 2**	**SRS1**	2.25	2.00	2.00
		SRS2	2.50	1.75	2.00
		Imp	**0.25**	**-0.25**	**0.00**
	Chapter 3	**SRS1**	4.75	3.75	4.00
		SRS2	5.00	4.00	3.50
		Imp	**0.25**	**0.25**	**-0.50**
	Chapter 4	**SRS1**	2.50	2.00	2.25
		SRS2	2.50	1.75	2.25
		Imp	**0.00**	**-0.25**	**0.00**
	Chapter 5	**SRS1**	1.75	1.75	2.50
		SRS2	2.00	1.75	1.00
		Imp	**0.25**	**0.00**	**-1.50**
	All Chapters Net Imp		**+0.75**	**-0.25**	**-2.00**
	Imp%		**-06.0%**	**-02.0%**	**-16.0%**
IEEE QC-8 Traceable (M=12.5) Where SRS1 (E1+E2)/2 SRS2 (E1+E2)/2	**Chapter 2**	**SRS1**	2.50	1.75	1.25
		SRS2	2.25	2.25	1.25
		Imp	**-0.25**	**0.50**	**0.00**
	Chapter 3	**SRS1**	5.00	3.75	3.75
		SRS2	4.75	3.50	4.00
		Imp	**-0.25**	**-0.25**	**0.25**
	Chapter 4	**SRS1**	2.50	1.75	2.25
		SRS2	2.00	1.75	1.75
		Imp	**-0.50**	**0.00**	**-0.50**
	Chapter 5	**SRS1**	2.00	1.75	1.75
		SRS2	1.75	1.50	1.25
		Imp	**-0.25**	**-0.25**	**-0.50**
	All Chapters Net Imp		**-1.25**	**0.00**	**-0.75**
	Imp%		**-10.0%**	**00.0%**	**-06.0%**

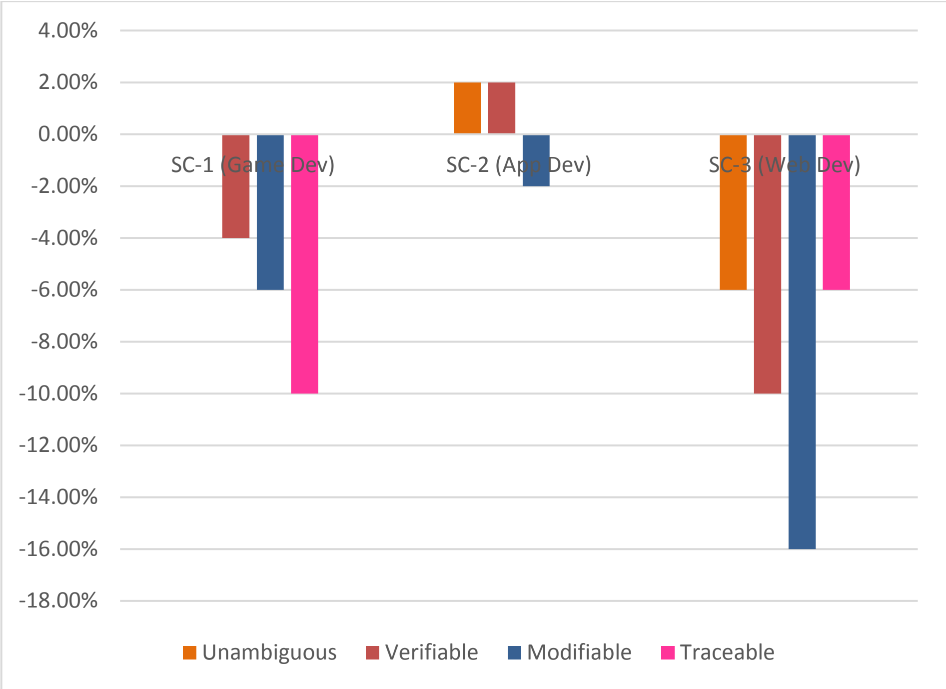

Figure-5.14B Industrial Study, SRS Results (Company-wise, Attributes Improvements)

Consider the table-5.15, which has been used to show the results of evaluations of all industrial study companies in form of IEEE quality attribute-wise complete results sheet. This table shows an overall improvement gained of each of IEEE quality attributes of correctness, completeness, consistency, ranking, unambiguousness, verifiability, modifiability and traceability. This table shows the details of improvements gained by each software company in all these quality attributes throughout the whole SRS chapters (chapter-1 to chapter-5). The table also shows the average improvement of all software companies in each quality attribute. The overall results of this table have also been shown in figure-5.15 as a pi-chart graph.

Table-5.15 Industrial Study, SRS Results (Attributes Wise)

	IEEE QC Attribute	SC-1 (Game Dev)	SC-2 (App Dev)	SC-3 (Web Dev)	All Companies Avg Imp
System Understanding Attributes	**System Scope Understandability**				
	IEEE QC-1 Correct	**+36.0%**	**+36.0%**	**+30.0%**	**+34.00%**
	IEEE QC-3 Complete	**+38.0%**	**+44.0%**	**+24.0%**	**+35.33%**
	System Feature Understandability				
	IEEE QC-4 Consistent	**+24.0%**	**+32.0%**	**+20.0%**	**+25.33%**
	IEEE QC-5 Ranked	**-24.0%**	**-32.0%**	**+32.0%**	**-08.00%**
Requirements Writing Attributes	**Requirements Writing Styles**				
	IEEE QC-2 Unambiguous	**00.0%**	**+02.0%**	**-06.0%**	**-01.33%**
	IEEE QC-6 Verifiable	**-04.0%**	**+02.0%**	**-10.0%**	**-04.00%**
	Requirements Writing Structures				
	IEEE QC-7 Modifiable	**-06.0%**	**-02.0%**	**-16.0%**	**-08.00%**
	IEEE QC-8 Traceable	**-10.0%**	**00.0%**	**-06.0%**	**-05.33%**
All Companies Avg SRS Imp = +08.5%					
09.2% - 08.5% = 0.7% Round Off Error					

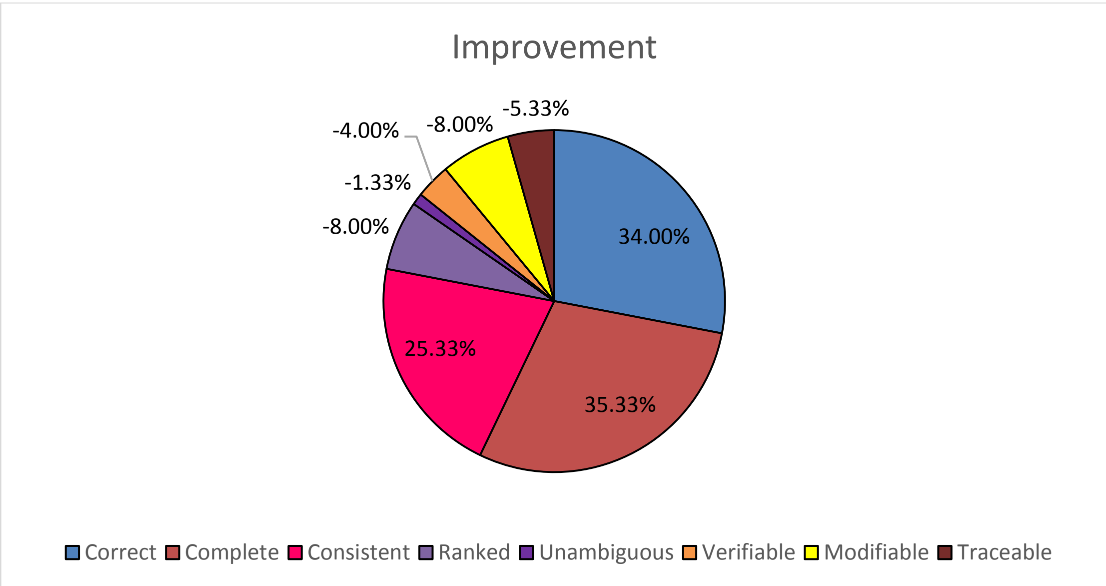

Figure-5.15 Industrial Study, SRS Results (Attributes Wise Improvement)

5.3 ANALYSIS OF FRAMEWORK EVALUATIONS

The overall analysis of the evaluation results obtained during pilot study and industrial study of the proposed framework show a very positive improvement gain in requirements elicitation process using proposed framework for global software development teams.

5.3.1 Overall Improvement

On average, an overall improvement of 11.3% (based on 13.4% improvement in pilot study and 9.2% improvement in industrial study) has been observed by using proposed framework for requirements elicitation process in global software development projects.

5.3.2 Improvement in Correctness

On average, an overall improvement of 31.6% in quality attribute of correctness (based on 29.2% improvements in pilot study and 34.0% improvements in industrial study) has been observed by using proposed framework for requirements elicitation process in global software development projects.

5.3.3 Improvement in Completeness

On average, an overall improvement of 31.1% in quality attribute of completeness (based on 27.0% improvements in pilot study and 35.3% improvements in industrial study) has been observed by using proposed framework for requirements elicitation process in global software development projects.

5.3.4 Improvement in Consistency

On average, an overall improvement of 20.6% in quality attribute of consistency (based on 15.8% improvements in pilot study and 25.3% improvements in industrial study) has been observed by using proposed framework for requirements elicitation process in global software development projects.

5.4 FRAMEWORK CONTRIBUTIONS

The overall analysis of the results obtained in this chapter show that the proposed framework contributes positively in the improvement of the requirements elicitation process for global software development teams working on offshore software development projects. The IEEE defined quality attributes of correctness, completeness, consistency, ranking, unambiguousness, verifiability, modifiability and traceability have been used to judge the improvements in the elicited requirements of the projects during whole process of requirements elicitation. It has been observed that the proposed framework positively contributed in the improvement of quality attributes of correctness, completeness and consistency which refer to the system understandability during requirements elicitation process. The system understandability directly represents the major issue of lake of understandability faced by requirements engineering teams during requirements elicitations in global software development contexts.

5.5 BENCHMARK WITH OTHER FRAMEWORKS

The proposed requirements elicitation framework is fully support user-centric framework for global software development teams working on requirements elicitation. The proposed framework covers all aspects of global software development along with additional support for traditional in-house software development. The framework structure is based on a hierarchical model which uses algorithmic solutions to select the most appropriate requirements elicitation teams, requirements elicitation techniques and requirements elicitation groupware tools. Consider the given table-5.16, which provides a comprehensive benchmarking analysis of proposed framework with already available frameworks for domain of requirements elicitation in global software development. It can be seen from the benchmarking analysis that the proposed framework provides a complete working solution for requirements elicitation teams working in global software development contexts.

Table-5.16 Benchmarking with Available RE-GSD Frameworks

		UCRE Framework (Chapter-4)	**FreGSD Framework (Section-2.8.4)**	**GlobReq Framework (Section-2.8.5)**	**REM Framework (Section-2.8.8)**
01	User-Centric Design	Yes	No	No	No
02	Personality Traits Base	Yes	No	No	No
03	Globalizational Context	Applicable	Applicable	Applicable	Applicable
04	Situational Context	Considered	Considered	Not Considered	Not Considered
05	Stakeholder's Analysis	Performed	Performed	Performed	Not Performed
06	Stakeholder's Training	Suggested	Not Suggested	Not Suggested	Not Suggested
07	RE-Team Selection	Provided	Not Provided	Not Provided	Not Provided
08	RE-Technique Selection	Provided	Not Provided	Not Provided	Not Provided
09	RE-Groupware Selection	Provided	Not Provided	Not Provided	Not Provided
10	Industrial Validation	Compliant	Compliant	Compliant	Compliant
11	Preference Analysis	Used	Not Used	Not Used	Not Used
12	Hierarchical Structure	Fully	Partially	Not	Fully
13	Algorithmic Nature	Fully	Not	Not	Not

14	Workflows Analysis	Performed	Performed	Partial Performed	Performed
15	Systematic Working	Yes	Yes	Yes	Yes

5.6 PERSONALITY TRAITS EFFECT ON QUALITY ATTRIBUTES

The big-five personality assessment model has been used to assess the personality traits of participants of the pilot study as well as industrial study. The big-five model was selected for personality assessment of participants due to its successful applications in domain of computer sciences and software engineering. This model has already been successfully used to assess the personality traits for different software development roles like software requirements engineering teams, software design and architecture teams, software development teams, software testing teams and software project management teams. According to this model, a person may have different scaling values of his personality based on five traits of Openness (O), Conscientiousness (C), Extroversion (E), Agreeableness (A) and Neuroticism (N).

Further, each trait can have low and high aptitudes or facets depending upon the range of values calculated on sliding scales. Therefore, there can be a total of thirty-two different possible personality combinations for any participant of study as is shown below in the given table-5.17.

Table-5.17 Different Variants of OCEAN Traits

N	C	E	A	O	OCEAN Pattern
L	L	L	L	L	OCEAN-00
L	L	L	L	H	OCEAN-01
L	L	L	H	L	OCEAN-02
L	L	L	H	H	OCEAN-03
L	L	H	L	L	OCEAN-04
L	L	H	L	H	OCEAN-05
L	L	H	H	L	OCEAN-06
L	L	H	H	H	OCEAN-07
L	H	L	L	L	OCEAN-08
L	H	L	L	H	OCEAN-09
L	H	L	H	L	OCEAN-10
L	H	L	H	H	OCEAN-11
L	H	H	L	L	OCEAN-12
L	H	H	L	H	OCEAN-13
L	H	H	H	L	OCEAN-14
L	H	H	H	H	OCEAN-15
H	L	L	L	L	OCEAN-16
H	L	L	L	H	OCEAN-17
H	L	L	H	L	OCEAN-18
H	L	L	H	H	OCEAN-19
H	L	H	L	L	OCEAN-20
H	L	H	L	H	OCEAN-21
H	L	H	H	L	OCEAN-22
H	L	H	H	H	OCEAN-23
H	H	L	L	L	OCEAN-24
H	H	L	L	H	OCEAN-25
H	H	L	H	L	OCEAN-26
H	H	L	H	H	OCEAN-27
H	H	H	L	L	OCEAN-28
H	H	H	L	H	OCEAN-29
H	H	H	H	L	OCEAN-30
H	H	H	H	H	OCEAN-31

The personality questionnaire form was developed in accordance with standard big-five personality assessment test provided by NEO-IPIP 50 Pool Inventory. Each big-five trait was characterized into binary (two) values by scaling up and scaling down the obtained range of values. Consider the given table-5.18 which shows the formulas that have been used to calculate the values of OCEAN trait patterns based on standard provided by big-five assessment guidelines.

Table-5.18 OCEAN Traits Value Calculator

Extrovert (E)											
	01	06	11	16	21	26	31	36	41	46	**E**
20	+	-	+	-	+	-	+	-	+	-	
Agreeableness (A)											
	02	07	12	17	22	27	32	37	42	47	**A**
14	-	+	-	+	-	+	-	+	+	+	
Conscientiousness (C)											
	03	08	13	18	23	28	33	38	43	48	**C**
14	+	-	+	-	+	-	+	-	+	+	
Neuroticism (N)											
	04	09	14	19	24	29	34	39	44	49	**N**
38	-	+	-	+	-	-	-	-	-	-	
Openness (O)											
	05	10	15	20	25	30	35	40	45	50	**O**
08	+	-	+	-	+	-	+	+	+	+	

After getting the values for five traits in form of one of thirty-two possible OCEAN patterns, the values are normalized to scale up or scale down.

Low (00-10) + Moderate (11-19) ➔ Scale-Down ➔ Low, L (0)

High (20-29) + Very High (30-40) ➔ Scale-Up ➔ High, H (1)

After this normalization the five traits gives us any one of the possible thirty-two trait patterns as mentioned earlier. The traits of conscientiousness and neuroticism has been used to perform support-oppose analysis to calculate support factors. These support factors show the overall health of the requirements elicitation process by selecting the most appropriate requirements elicitation teams, techniques and groupware tools. The results obtained during pilot study and industrial study has shown that the selection of most appropriate requirements elicitation teams, techniques and groupware tools overall positively contributed in the improvement of requirements elicitation process by improving certain quality attributes. The IEEE standard Std. 830 based on eight quality parameters for SRS have been used to judge the improvements in requirements elicitation process. There were eight quality attributes of correctness, completeness, consistency, ranking, unambiguousness, verifiability, modifiability and traceability.

The results obtained has revealed that the personality traits-based selection of requirements elicitation teams, techniques and groupware tools has improved the quality factors of correctness, completeness and consistency. An overall improvement of 31.6% in quality attribute of correctness (based on 29.2% improvements in pilot study and 34.0% improvements in industrial study) has been observed by using proposed personality traits-based framework for requirements elicitation process in global software development projects. Similarly, an overall improvement of 31.1% in quality attribute of completeness (based on 27.0% improvements in pilot study and 35.3% improvements in industrial study) has been observed by using proposed personality traits-based framework for requirements elicitation process in global software development projects. Similarly, an overall improvement of 20.6% in quality attribute of consistency (based on 15.8% improvements in pilot study and 25.3% improvements in industrial study) has been observed by using proposed personality traits-based framework for requirements elicitation process in global software development projects.

5.7 CHAPTER SUMMARY

This chapter initially presents the evaluations of proposed framework in form of a controlled experiment (performed as pilot study) using undergraduate level students of a university in Pakistan. The chapter later-on presents the evaluation of the proposed framework in form of an industrial experiment (performed as real study) using three offshore software development companies working in Pakistan and doing offshore software development for different clients belonging to USA and Canada. The chapter presents the evaluation process of proposed framework by explaining sample characteristics, experiment characteristics, scenario characteristics and results analysis for both types of studies. The chapter presents the overall analysis of the complete evaluation process after the descriptions of the pilot study and industrial study of proposed framework. At the end, chapter presents framework contributions in form of quality improvements in requirements elicitation process for global software development projects.

CHAPTER SIX

DISCUSSION AND CONCLUSION

This chapter presents the discussions on different aspects of research formulated in this thesis. The purpose of this chapter is to provide a deep insight on the need of the conducted research and its consequential outcomes to meet the defined research objectives. The chapter also provides a sharp elaboration on the authenticity of the adopted research methodology during the investigation of planned research. The chapter also presents a short elaborative argumentation on the philosophy of the proposed framework and behind the scene conception of the proposed framework. The chapter also presents elaborations and argumentations on overall evaluation process carried-out for the performance evaluation of the proposed framework design.

6.1 DISCUSSION ON FORMULATED RESEARCH QUESTIONS

The chapter-1 (introduction) of the thesis presented four research questions that have been formulated for anticipated research endeavor. Each research question was very precisely formulated to concretely dig-out the research agenda supporting the selected research topic. ***Research Question-1*** was striving to find out the main influencing/deriving factors on which the requirements elicitation process depends for global software development teams. The investigation revealed that main influencing factors for requirements elicitation process running in global software development projects can be divided into two major classes of traditional requirements elicitation factors and specific global software development context-based factors. The traditional requirements elicitation factors were investigated to take a deep insight which revealed that such factors may include organizational factors, stakeholder's factors, project factors, process factors and product factors. The specific global software development context factors were investigated to take a deep insight which revealed that such factors may include geographical distribution factors, temporal diversity factors, cultural diversity factors, knowledge management factors, team trust factors and coordination and control factors. ***Research Question-2*** was striving to find out, the effects of the personality traits factor on the requirements elicitation process for global software development teams. The investigation revealed that personality traits of participants of requirements elicitation process have a great influence on the whole process of requirements elicitations in traditional environments as well as in geographically distributed environments. ***Research Question-3*** was striving to find out, the specific effects of the user personality traits factor on the requirements elicitation process for global software development teams. The experimentation performed for the evaluation of the proposed framework confirmed that considerations of user personality traits during requirements elicitation team compositions, technique selections and tool selection improves the overall elicitation process quality. The experimented work revealed that user personality traits consideration specifically improved the system understandability of participants in requirements elicitation process for global software development teams. ***Research Question-4*** was striving to find out, how a user-centric requirements elicitation framework can be devised to incorporate user personality traits to improve the requirements elicitation process for global software development teams? The investigations revealed that a user-centric requirements elicitation framework can be devised by considering the user personality traits during the requirements elicitation team composition, technique selection and tool selection. The user personality traits have a great impact on the overall process of requirements elicitation in traditional as well as in global software development environments.

6.2 DISCUSSION ON IDENTIFIED RESEARCH GAPS

The chapter-2 (literature review) of the thesis presented a very comprehensive literature review about the most recently available stat-of-the-art research about the selected research topic of this thesis. The chapter presented a very brief outline about existing research gaps available for further investigation and exploration. The chapter presented five very concrete research gaps identified from the literature review. ***Research Gap-1*** identified that, there was an opportunity for researchers to investigate the contributions of personality traits in requirements elicitation process for global software development projects. ***Research Gap-2*** identified that, there was an opportunity for researchers to investigate such kind of models or frameworks, which should incorporate these situational factors to see their impact on requirements elicitation process for global software development projects. ***Research Gap-3*** identified that, there was an opportunity for researchers to devise groupware technology selection process integrated with the user's personality assessment process to better facilitate the users. ***Research Gap-4*** identified that, there was an opportunity for researchers to investigate such kind of processes, techniques, methods or methodologies that can incorporate user personality traits to customize their internal procedures to facilitate the users during requirements elicitation process in global software development contexts. ***Research Gap-5*** identified that, there was an opportunity for researchers to investigate a requirements elicitation framework incorporated with user personality traits assessment procedures to customize the internal tasks of elicitation process. A concrete research problem was formulated for anticipated research after taking a deep insight on the existing research opportunities identified by five highlighted research gaps.

6.3 DISCUSSION ON APPLIED RESEARCH METHODOLOGY

The chapter-3 (research methodology) of the thesis presented the complete research methodology that was followed during the whole investigation of the anticipated research agenda. Initially a comprehensive literature review was made using latest research articles published in journals and conferences of international repute which revealed the set of external factors which effect the requirements elicitation process. The influencing factors included traditional factors of requirements elicitation as well as global software development context factors. Considering all these influencing factors, a requirements elicitation framework was devised for global software development teams to improve the overall quality of the requirements elicitation process. The proposed framework evaluation was carried-out using globally accepted approach of initially conducting a pilot study using a controlled experiment and later conducting industrial study using a real time software industry environment. This two-phase evaluation process enabled the investigators to deeply observe the quality improving factors of requirements elicitation process using proposed framework. The probability sampling strategy was used to select the samples from the available population for the small-scale academic evaluation (pilot study) as well as full-scale industrial evaluation (real study) of the proposed framework. The clustering sampling method was used to select the samples from available population. In pilot study, the clustering method was applied to select only those students for study who had successfully passed software requirements engineering course. In industrial study, clustering method was applied to select only those software development companies, which were located in nearby locality of researcher, and their projects were purely offshore projects managed by globally distributed software development teams. The companies were randomly selected by just considering their context of projects, team distributions and physical locality with respect to principal researcher.

6.4 DISCUSSION ON CRAFTED FRAMEWORK DESIGN

The chapter-4 (proposed framework) of the thesis presented the complete design layout of the proposed framework by explaining it from top-level abstract entity to bottom-level concrete algorithms and processes. The main contribution of the proposed framework is its user-centeredness capability incorporated to customize the different processes and algorithms during the whole process of requirements elicitation. The user-centeredness is incorporated in the proposed framework by using parameter of user personality traits using big-five personality assessment model. The proposed framework will help the software industry to understand the impact of user-centeredness on requirements elicitation process for global software development teams. The proposed framework will help the software industry to understand the general impact of personality traits factor on requirements elicitation process for global software development teams. The proposed framework will help the software industry to understand the specific impact of user personality traits on requirements elicitation process for global software development teams. The proposed framework will contribute in improvement of software development process by improving requirements elicitation process for global software development teams. The proposed framework will serve as an asset for software industry to plan the most effective requirements elicitation contexts for global software development teams.

6.5 DISCUSSION ON EVALUATION PROCESS

The chapter-5 (framework evaluation) of the thesis presented the framework evaluation process in a very comprehensive manner. The proposed framework assessment was carried out at two levels including initial pilot study based controlled experiment and final industrial study based on industry-oriented experiment. The assessment of the proposed framework was planned in such a manner that all internal processes, algorithms and techniques of the framework were comprehensively assessed as per guidelines provided by the software development industry. ***Controlled Experiment*** was performed on a group of hundred students belonging to an undergraduate program a university. The students were randomly divided into different groups of equal size and subsequently hypothetically working software development teams were established by merging randomly selected two groups into one software development team. All software development teams were asked to act like a global software development teams to work on two different software development projects using two different development iterations. In the first iteration, the students were given a fixed time margin to elicit and document the requirements of a hypothetical project using traditional global software development practices. In the second iteration, the students were again given a fixed time margin (equal to previous project time margin) to elicit and document the requirements of a second hypothetical project using proposed requirements elicitation framework. In order to perform the requirements elicitation during second project, the group roles were reversed to remove the group-based biasness. The results of both iterations were translated from qualitative attributes to quantitative values using expert opinions. The quantitative results of both iterations were compared to see the improvements in the requirements elicitation process using the proposed requirements elicitation framework. ***Industrial Experiment*** was performed on the real software development projects running in three different global software development companies. The software development companies were selected on basis of the requirements elicitation team geographical distributions and nature of the software development projects. The first company was based on the low geographical distribution in requirements elicitation teams where analyst team members were in one country while the user team members were in another country. The second company was based on the medium geographical distribution in requirements elicitation teams where analyst team members were in one country while the user team members were distributed in multiple countries. The third company was based on the high geographical distribution in requirements elicitation teams where analyst team members were in multiple countries as well as the user team members were also in multiple countries. Each company was asked to develop the requirements specification document for their project using two iteration where first iteration was run without using proposed framework while the second iteration was run with using the proposed framework. The results of both iterations were translated from qualitative attributes to quantitative values using expert opinions. The quantitative results of both iterations were compared to see the improvements in the requirements elicitation process using the proposed requirements elicitation framework. ***Evaluation Results*** obtained during pilot study and industrial study of the proposed framework show a very positive improvement gain in requirements elicitation process using proposed framework for global software development teams. An overall improvement of 11.3% (based on 13.4% improvement in pilot study and 9.2% improvement in industrial study) has been observed by using proposed framework. An improvement of 31.6% in quality attribute of correctness (based on 29.2% improvements in pilot study and 34.0% improvements in industrial study) has been observed by using proposed framework. An improvement of 31.1% in quality attribute of completeness (based on 27.0% improvements in pilot study and 35.3% improvements in industrial study) has been observed by using proposed framework. An improvement of 20.6% in quality attribute of consistency (based on 15.8% improvements in pilot study and 25.3% improvements in industrial study) has been observed by using proposed framework.

6.6 DISCUSSION ON SIGNIFICANCE OF WORK

The main concern of this research is to provide a user-centric requirements elicitation framework, which is incorporated with user personality traits (along with other relevant factors of RE-GSD) for global software development teams. The envisioned user-centric framework is expected to provide an improved mechanism for requirements elicitation process for those environments where the software development team as-well-as product users are geographically distributed in different parts of world. The interactions between software development teams and product users become a more challenging task in offshore projects due to the variations in geological locations, time zones, languages and culture of participants as compared to traditional in-house software development contexts. The proposed framework will help the software industry to understand the impact of user-centeredness on requirements elicitation process for global software development teams. The proposed framework will help the software industry to understand the general impact of personality traits factor on requirements elicitation process for global software development teams. The proposed framework will help the software industry to understand the specific impact of user personality traits on requirements elicitation process for global software development teams. The proposed framework will contribute in improvement of software development process by improving requirements elicitation process for global software development teams. The proposed framework will serve as an asset for software industry to better plan the most effective/productive requirements elicitation contexts for global software development teams.

6.7 FINAL RECOMMENDATIONS

The proposed framework is drafted with an innovative hierarchical structural design, which enables the users to go through all main task of requirements elicitation process executing in traditional as well as in global software development projects. The evaluation results obtained through pilot testing and industrial testing justified the worth of proposed design, which will benefit modern software development strategies adopted for global software development teams. The evaluation of proposed framework also revealed its multiple beneficial characteristics that make it a valuable asset for modern software development industry. The major characteristics include improvement in quality of requirements elicitation process along with its comprehensiveness of design encompassing all major processes and algorithms of requirements elicitation process. The proposed framework will help the software industry to understand the impact of user-centeredness on requirements elicitation process for global software development teams. The framework will also help the software industry to understand the impact of user personality traits on requirements elicitation process for global software development teams. The framework will contribute in improvement of software development process by improving requirements elicitation process for global software development teams. The framework will serve as an asset for software industry to plan the most productive requirements elicitation contexts for global software development teams. It is highly recommended that proposed framework should be automated in requirements elicitation tools used for global software development projects. The automation of the proposed framework will enable the users to easily apply all of its algorithms and internal processes very efficiently to accomplish the anticipated requirements elicitation process.

6.8 IMPLICATIONS AND CONCLUSION

The requirements elicitation is considered as the one of the most crucial and challenging activities in the software development life cycle process. The requirements elicitation process is full of cross-sectional conversations between development teams and product users to conceptualize the anticipated software product. The quality of requirements elicitation process is mostly dependent on the richness and accuracy of system understandability via formal and information conversations. The interactive conversational nature of the requirements elicitation process putts its core dependency on the human factor involved in this process like human natures, working styles, collaborative patterns, participant perceptive capabilities and personality traits. The role of participant's personality traits in requirements elicitation process is vital in traditional as well as global contexts. The globalization factors existing in requirements elicitation teams more prominently base its dependability on participant's personality traits. The user personality traits play a key role in user-centric requirements elicitation process where different tasks are customized to better facilitate the members of user teams participating in elicitation process. Hence, there was a serious need to devise a requirements elicitation framework that should be integrated with user personality traits to make it a user-centric process for traditional as well as global software development contexts. Considering this deficiency in the existing practices of requirements engineering for geographically distributed teams, a user-centric requirements elicitation framework has been proposed for global software development teams. The proposed framework will help the software development industry to better compose their requirements elicitation teams and consequential requirements elicitation process. The proposed framework will serve as a valuable asset for software development companies to further improve the quality of requirements elicitation process running in global software development projects.

6.9 DIRECTIONS FOR FUTURE WORK

The proposed framework is a theoretical framework which has been tested using controlled experiment during pilot study and industrial experiment during industrial study. There can be different possible directions for the future work of the proposed framework to further enhance the framework contributions in the body of knowledge of domain of software engineering. There can be two major directions for the future work of the proposed framework including its philosophical extensions to theoretically contribute in the existing literature of the domain and its industry-oriented implementations as software development tool. ***First Main Direction*** for the future work of proposed framework can be the extended industrial testing of the proposed framework using larger sized industrial samples. The industrial study of the framework has been performed on small to medium sized software development companies working in global software development projects. The industrial testing of the proposed framework can be extended to large and very large sized software development companies. The extended industrial testing of the proposed framework on large to very large sized companies will enable the researchers to see the impact of framework contributions on the requirements elicitation process in a more rigorous manner. Also, the different kinds of project with high complexity can be used in the extended evaluation of proposed framework, which will help the researchers to understand the impact of project characteristics variations on the framework performance. The extended testing of the framework can be planned to apply the proposed framework on iterative spiral processes of requirements engineering rather than testing it on traditional sequential processes. ***Second Main Direction*** for the future work of proposed framework can be the implementation of framework as a requirements elicitation tool for global software development teams. The automation of the proposed framework in form of requirements elicitation tool will enable the users to more efficiently and quickly apply the framework processes and algorithms during requirements elicitation team composition, technique selection and groupware tool selection. The implementation of proposed framework can be in form of a web service which will enable more participants to use the framework for requirements elicitation works in their offshore projects. This web service-based implementation will enhance the beta testing capability for the proposed framework by engaging the software development teams actually doing offshore development around the world.

6.10 CHAPTER SUMMARY

This chapter presents the discussions and recommendations for the proposed framework by considering its different aspects of conceptualization, design, testing and applicability. The chapter has been organized to discuss core agendas and main streamline focus of each chapter of the thesis by giving extended elaborations on the stated matters. The chapter presents a discussion on formulated research questions and research objectives for the proposed framework. Similarly, the chapter presents a discussion on the identified research gaps that have been used to formulate the main research question of the anticipated investigation. Similarly, the chapter presents a discussion on the research methodology that has been successfully used to draft the proposed framework. Similarly, the chapter presents a discussion on the complete design of the proposed framework from abstract level to concrete level hierarchical structure. Similarly, the chapter presents a discussion on the complete evaluation process that has been carried-out during the controlled experiment and industrial experiment of the proposed framework. The chapter also presents the final recommendations about the design and applicability of the proposed framework for modern software development industry working on offshore software development projects. The chapter also presents concluding remarks along with future work that can be carried-out on the proposed framework philosophy.

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APPENDIX-A

DATA COLLECTION FORMS

DATA COLLECCTION FORM, DCF01-PQF
(PERSONALITY QUESTIONAIRE FORM)

SECTION-I
RESPONDENT (USER) PROFILE

Full Name	
Nick Name	
Gender	
Age (Years)	
Qualification	
Email Address	
Organizational Information	
Company Name	
Hosting Country	
Locating City	
Profile/Sector	
Designation	

SECTION-II
TEST DETAILS (QUESTIONNAIRE)

Source: https://ipip.ori.org/New_IPIP-50-item-scale.htm

DATA COLLECCTION FORM, DCF02-PIF
(PERSONAL INFORMATION FORM)

SECTION-I
Team Member Personal Information

Company Name	
Full Name	
Nick Name	
Gender	
Age (Years)	
Qualification	
Email Address	
Native Country	
Native Language	
Any English Exam Passed	**IF YES** (Provide Complete Exam Details)

(Like IELTS)				
English Language Proficiency	**Reading**	Poor	Moderate	Good
	Writing	Poor	Moderate	Good
	Listening	Poor	Moderate	Good
	Speaking	Poor	Moderate	Good
	Net English Proficiency			
Cross-Cultural Experience	**Cross-Cultural Knowledge**	Poor	Moderate	Good
	Cross-Cultural Interaction	Poor	Moderate	Good

DATA COLLECCTION FORM, DCF03-WIF
(WORK INFORMATION FORM)

SECTION-I
Team Members Working Information

Name							
Nick Name							
Designation							
Job Des							
Organization							
Office Place							
Time Zone	**GMT**						
Availability Schedule		**MON**	**TUE**	**WED**	**THU**	**FRI**	**SAT**	**SUN**
	Time In							
	Time Out							
	Break In							
	Break Out							
RE Role	**Analyst Team**				**User Team**			
Work Expr								
IT Expr								
RE Expr								
GSD Expr								

SECTION-II
Team Members Preference Information

Time Preference	

RE Technique Preference	**Technique Type**	Conversational Methods	Observational Methods	Analytical Methods	Synthetic Methods
	Technique Mode	Group Based		Non-Group Based	
RE Tools Preference	Asynchronous			Synchronous	
	Visual			Verbal	
	Active			Reflective	

DATA COLLECCTION FORM, DCF04-PIF (PROJECT INFORMATION FORM)

SECTION-I Project Structural Information

Project Title						
Project Type						
Project Budget						
Project Sched						
Project Status						
Project Resources	**Hardware Resources**		**Software Resources**		**Other Resources**	
	Available	**Required**	**Available**	**Required**	**Available**	**Required**
	Deficiency		**Deficiency**		**Deficiency**	
Project Deliverables						
Project Milestones						
Project Risks						

SECTION-II Project Situational Context Information

Organization Factors	**Organization Resources**	
	Organization Strategies	
	Organization Standards	

<table>
<tr><td rowspan="3"></td><td>Organization Culture</td><td colspan="3"></td></tr>
<tr><td>Organization Maturity</td><td colspan="3"></td></tr>
<tr><td>Organization Environment</td><td colspan="3"></td></tr>
<tr><td rowspan="8">Stakeholders Factors</td><td>Project Primary Stakeholders Constraints</td><td colspan="3"></td></tr>
<tr><td>Project Seconda Stakeholders Constraints</td><td colspan="3"></td></tr>
<tr><td rowspan="3">Requirement Elicitation Stakeholders Constrains</td><td>Primary Stakeholders Constraints</td><td colspan="2">Secondary Stakeholders Constraints</td></tr>
<tr><td>Most Important</td><td>More Important</td><td>Less Important</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Requirement Elicitation Team Structure</td><td>Analyst Team Structure</td><td colspan="2">User Team Structure</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td>Stakeholders Interaction Mod</td><td colspan="3"></td></tr>
<tr><td rowspan="6">Project Factors</td><td>Application Domain Characteristics</td><td colspan="3"></td></tr>
<tr><td>Solution Domain Characteristics</td><td colspan="3"></td></tr>
<tr><td>Project Attribut Characteristics</td><td colspan="3"></td></tr>
<tr><td>Requirements Characteristics</td><td colspan="3"></td></tr>
<tr><td>Project Risks Characteristics</td><td colspan="3"></td></tr>
<tr><td>Project Management</td><td colspan="3"></td></tr>
<tr><td>Process Factors</td><td colspan="4"></td></tr>
<tr><td>Product Factors</td><td colspan="4"></td></tr>
</table>

SECTION-III
Project Globalizational Context Information

Temporal Diversity	Low	Medium	High

Cultural Diversity	Low		Medium	High
Linguistic Diversity	Low		Medium	High
Team Trust Level	Low		Medium	High
Coordination & Control	Low		Medium	High
Knowledge Management	**Knowledge Types**		**Knowledge Extraction**	
	Explicit	**Tacit**	**Strategies**	**Standards**

DATA COLLECCTION FORM, DCF05-SIF
(STAKEHOLDERS INFORMATION FORM)

SECTION-I
RE Stakeholders Classifications

Project Title		
Developer Comp		
Client Comp		
RE Primary Stakeholders List	**Most Important Role**	
	Analyst Team: **User Team:**	
RE Secondary Stakeholders List	**More Important Role**	**Less Important Role**
	Analyst Team: **User Team:**	**Analyst Team:** **User Team:**

SECTION-II
RE Stakeholders Conflicts Logging

RE Primary Stakeholders Mutual Conflicts	**Most Important Role**	
RE Secondary Stakeholders Mutual Conflicts	**More Important Role**	**Less Important Role**
RE Primary & Secondary Stakeholders Across Conflicts		

DATA COLLECCTION FORM, DCF06-RCF
(REQUIREMENTS COLLECTION FORM)

SECTION-I
Team Information Sheet

Project Title		
Company		
Elicitation Techniques Used	**Primary Techniques Used**	
	Secondary Techniques Used	
Elicitation Tools Used	**Asynchronous Tools Used**	
	Synchronous Tools Used	
Team Type	**Team Role**	**Full Name**
Analyst Team		
User Team		

SECTION-IIA
IEEE SRS Chapter-1 (Introduction)

1.1 Purpose

1.2 Document Conventions

1.3 Intended Audience and Reading Suggestions

1.4 Product Scope

1.5 References

SECTION-IIB
IEEE SRS Chapter-2 (Overall Description)

2.1 Product Perspective

2.2 Product Functions

2.3 User Classes and Characteristics

2.4 Operating Environment

2.5 Design and Implementation Constraints

2.6 User Documentation

2.7 Assumptions and Dependencies

SECTION-IIC
IEEE SRS Chapter-3 (System Features)

3.1 System Feature-1

3.1.1 Description and Priority

3.1.2 Stimulus/Response Sequences

3.1.3 Functional Requirements

REQ-1:
REQ-2:
.
REQ-N:

3.2 System Feature-2

.

So on …

SECTION-IID **IEEE SRS Chapter-4 (External Interface Requirements)**

4.1 User Interfaces

4.2 Hardware Interfaces

4.3 Software Interfaces

4.4 Communications Interfaces

SECTION-IIE **IEEE SRS Chapter-5 (Other Non-Functional Requirements)**

5.1 Performance Requirements

5.2 Safety Requirements

5.3 Security Requirements

5.4 Software Quality Attributes

5.5 Business Rules

APPENDIX-B

DATA ANALYSIS FORMS

DATA ANALYSIS FORM, DAF01-PAF (PERSONALITY ASSESSMENT FORM)

SECTION-I **RESPONDENT DETAILS**

Company	
Full Name	
Nick Name	

SECTION-II **EVALUATOR DETAILS**

Evaluator Domain				
Full Name				
Nick Name				
Designation				
Qualification				
Contact Number	**Landline**		**Mobile**	
Email Address				

SECTION-III **PERSONALITY EVALUATION SHEET**

Source: https://ipip.ori.org/New_IPIP-50-item-scale.htm

Extrovert (E)																					
	01		06		11		16		21		26		31		36		41		46		**E**
20	+		-		+		-		+		-		+		-		+		-		

Agreeableness (A)																					
	02		07		12		17		22		27		32		37		42		47		**A**
14	-		+		-		+		-		+		-		+		+		+		

Conscientiousness (C)																					
	03		08		13		18		23		28		33		38		43		48		**C**
14	+		-		+		-		+		-		+		-		+		+		

Neuroticism (N)																					
	04		09		14		19		24		29		34		39		44		49		**N**
38	-		+		-		+		-		-		-		-		-		-		

Openness (O)																					
	05		10		15		20		25		30		35		40		45		50		**O**
08	+		-		+		-		+		-		+		+		+		+		

BIG-FIVE TRAITS SUMMARY

The any trait can have a value between 0-40. Where Low = 00-10, Moderate = 11-19, High = 20-29, Very High = 30-40

O	C	E	A	N

SECTION-IV
PERSONALITY PATTERN SHEET

Trait Scaling

Low (00-10) + Moderate (11-19) ➔ Scale-Down	**Low**	**L (0)**
High (20-29) + Very High (30-40) ➔ Scale-Up	**High**	**H (1)**

OCEAN Trait Pattern

O	C	E	A	N

DATA ANALYSIS FORM, DAF02-TCF
(TEAM CHARACTERISTICS FORM)

(ANALYSIS SHEET) SC1

1-Globalizational Factors Applied			**Recommended Technique & Tool**
Temporal Overlap			
Cultural Diversity			
Knowledge Management			
2-Situational Factors Applied			**Recommended Technique & Tool**
Organizational Factors	**Structure: Resources: Standards: Strategies:**		
Stakeholders Factors	**Analyst Team Characteristics:** **User Team Characteristics: Interaction Mode:**		
Project Factors	**Project Budget: Project Schedule:** **Project Resources: Project Risks:**		
3-Team Preferences			**Recommended Technique & Tool**

Analyst Preference	Conversational & Analytical Methods, Group Techniques					
User Preferences	Conversational Methods, Introspection, Group Techniques					
4-User Personality Traits						
Part-1: Elicitation Technique Selection						**Recommended Technique**
	User-1	**User-2**	**User-3**	**User-4**	**User-5**	
OCEAN Pattern						
(C, N) Support/Oppose Analysis						
Elicitation Technique Selection						
Part-2: Elicitation/Groupware Tool Selection						**Recommended Groupware Tool**
	User-1	**User-2**	**User-3**	**User-4**	**User-5**	
OCEAN Pattern						
Visual/Verbal						
Active/Reflective						
Support/Oppose Analysis Factor-2 (C, N)						
Support/Oppose Analysis Factor-1 (Org, Stk)						
Net Support Factor (NSF)						
Finally Selected Tools & Techniques (Maximum Two Tools & Techniques)						
Part-1 (Selected Main Elicitation Techniques): **Part-2 (Selected Groupware Tools):**						

DATA ANALYSIS FORM, DAF03A-TEF
(TRAINING EVALUATION FORM) RE TRAINING

ANSWER THE FOLLOWING SHORT QUESTIONS CONCISELY

Sr#	Q-A	Descriptions	Marks
01	**Q**	What are different tasks performed during domain understanding process?	**/ 10**
	A		
02	**Q**	What are different tasks performed during organization understanding process?	**/ 10**
	A		

03	**Q**	What are different tasks performed during project contextual analysis?	**/ 10**
	A		
04	**Q**	What are different tasks performed during stakeholder's analysis process?	**/ 10**
	A		
05	**Q**	What are different sources of requirements during requirements elicitation process?	**/ 10**
	A		
06	**Q**	What are main classes of different types of requirements elicitation techniques?	**/ 10**
	A		
07	**Q**	What are different types of tools used in traditional requirements elicitation process?	**/ 10**
	A		
08	**Q**	What are different tasks performed during elicitation session preparation?	**/ 10**
	A		
09	**Q**	What are different tasks performed during requirements elicitation session?	**/ 10**
	A		
10	**Q**	What are different tasks performed after requirements elicitation session ending?	**/ 10**
	A		
		Total Marks	**/100**

DATA ANALYSIS FORM, DAF03B-TEF
(TRAINING EVALUATION FORM) GSD TRAINING

ANSWER THE FOLLOWING SHORT QUESTIONS CONCISELY

Sr#	Q-A	Descriptions	Marks
01	**Q**	How global software development practice is different from the traditional software development?	**/ 10**
	A		
02	**Q**	How virtual software development teams are different from traditionally collocated software development teams?	**/ 10**
	A		
03	**Q**	What are major benefits of global software development strategy as compared to traditional software development?	**/ 10**
	A		
04	**Q**	What are major drawbacks of global software development strategy as compared to traditional software development?	**/ 10**
	A		
05	**Q**	What do we mean by geographical distribution in global software development process?	**/ 10**
	A		

06	Q	What do we mean by temporal dispersion in global software development process?	/ 10
	A		
07	Q	What do we mean by cultural diversity in global software development process?	/ 10
	A		
08	Q	What do we mean by linguistic diversity in global software development process?	/ 10
	A		
09	Q	How knowledge management is performed in global software development environments?	/ 10
	A		
10	Q	What kind of challenges are associated with coordination and control process in global software development?	/ 10
	A		
		Total Marks	**/100**

DATA ANALYSIS FORM, DAF03C-TEF
(TRAINING EVALUATION FORM) SRS TRAINING

ANSWER THE FOLLOWING SHORT QUESTIONS CONCISELY

Sr#	Q-A	Descriptions	Marks
01	Q	What do we mean by IEEE quality attribute "Correct" in software requirements specification document?	/ 10
	A		
02	Q	What do we mean by IEEE quality attribute "Unambiguous" in software requirements specification document?	/ 10
	A		
03	Q	What do we mean by IEEE quality attribute "Complete" in software requirements specification document?	/ 10
	A		
04	Q	What do we mean by IEEE quality attribute "Consistent" in software requirements specification document?	/ 10
	A		
05	Q	What do we mean by IEEE quality attribute "Ranked" in software requirements specification document?	/ 10
	A		
06	Q	What do we mean by IEEE quality attribute "Verifiable" in software requirements specification document?	/ 10
	A		
07	Q	What do we mean by IEEE quality attribute "Modifiable" in software requirements specification document?	/ 10
	A		
08	Q	What do we mean by IEEE quality attribute "Traceable" in software requirements specification document?	/ 10
	A		

09	Q	What do we mean by quality attribute "Clearness" in software requirements specification document?	/ 10
	A		
10	Q	What do we mean by quality attribute "Redundant" in software requirements specification document?	/ 10
	A		
		Total Marks	**/100**

DATA ANALYSIS FORM, DAF04-REF
(REQUIREMENTS EVALUATION FORM)

SECTION-I
Evaluator Detailed Information

Project Title			
Evaluator Domain			
Full Name			
Nick Name			
Designation			
Qualification			
Email Address			
Work Experience			
RE Experience			
Organization Details			
Org Name			
Org Business			
Org Address			
Org Type	**Small** (01-10 Employees)	**Medium** (11-50 Employees)	**Large** (Above 50 Employees)
RE Team Distribution	**Low Geographical Distribution**	**Medium Geographical Distribution**	**High Geographical Distribution**
	Analyst = Single Country User = Single Country	Analyst = Single Country User = Multiple Countries Analyst = Multiple Countries User = Single Country	Analyst = Multiple Countries User = Multiple Countries
SRS Marks = / 100			

SECTION-II
IEEE SRS Chapter-2 Evaluation

Total Marks = 20 (8 x 2.5)

	Section 2.1, … , Section 2.7
IEEE QC-1 Correct	

IEEE QC-2 Unambiguous	
IEEE QC-3 Complete	
IEEE QC-4 Consistent	
IEEE QC-5 Ranked	**N. A**
IEEE QC-6 Verifiable	
IEEE QC-7 Modifiable	
IEEE QC-8 Traceable	
Total Obtained Marks	

SECTION-II
IEEE SRS Chapter-3 Evaluation

Total Marks = 40 (8 x 5)

	Section 3.1, … , Section 3.N
IEEE QC-1 Correct	
IEEE QC-2 Unambiguous	
IEEE QC-3 Complete	
IEEE QC-4 Consistent	
IEEE QC-5 Ranked	
IEEE QC-6 Verifiable	
IEEE QC-7 Modifiable	
IEEE QC-8 Traceable	
Total Obtained Marks	

SECTION-II
IEEE SRS Chapter-4 Evaluation

Total Marks = 20 (8 x 2.5)

	Section 4.1, … , Section 4.4
IEEE QC-1 Correct	
IEEE QC-2 Unambiguous	
IEEE QC-3 Complete	
IEEE QC-4 Consistent	
IEEE QC-5 Ranked	**N. A**
IEEE QC-6 Verifiable	
IEEE QC-7 Modifiable	
IEEE QC-8 Traceable	
Total Obtained Marks	

SECTION-II
IEEE SRS Chapter-5 Evaluation

Total Marks = 20 (8 x 2.5)

	Section 5.1, … , Section 5.5
IEEE QC-1 Correct	
IEEE QC-2 Unambiguous	
IEEE QC-3 Complete	
IEEE QC-4 Consistent	
IEEE QC-5 Ranked	
IEEE QC-6 Verifiable	
IEEE QC-7 Modifiable	
IEEE QC-8 Traceable	
Total Obtained Marks	