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The impact of RE process factors and organizational factors during alignment between RE and V&V

Systematic Literature Review and Survey

Srinivasu Akkineni

Faculty of Computing
Blekinge Institute of Technology
SE-371 79 Karlskrona Sweden

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Contact Information:

Author(s):

Srinivasu Akkineni

srinivasu.akkineni@gmail.com

University advisor:

Dr. Krzysztof Wnuk

Dept. of Software Engineering

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

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

ABSTRACT

Context: Requirements engineering (RE) and Verification and validation (V&V) areas are treated to be integrated and assure successful development of the software project. Therefore, activation of both competences in the early stages of the project will support products in meeting the customer expectation regarding the quality and functionality. However, this quality can be achieved by aligning RE and V&V. There are different practices such as requirements, verification, validation, control, tool etc. that are followed by organizations for alignment and to address different challenges faced during the alignment between RE and V&V. However, there is a requisite for studies to understand the alignment practices, challenges and factors, which can enable successful alignment between RE and V&V.

Objectives: In this study, an exploratory investigation is carried out to know the impact of factors i.e. RE process and organizational factors during the alignment between RE and V&V. The main objectives of this study are:

1. To find the list of RE practices that facilitate alignment between RE and V&V.
2. To categorize RE practices with respect to their requirement phases.
3. To find the list of RE process and organizational factors that influence alignment between RE and V&V besides their impact.
4. To identify the challenges that are faced during the alignment between RE and V&V.
5. To obtain list of challenges that are addressed by RE practices during the alignment between RE and V&V.

Methods: In this study Systematic Literature Review (SLR) is conducted using snowballing procedure to identify the relevant information about RE practices, challenges, RE process factors and organizational factors. The studies were captured from Engineering Village database. Rigor and relevance analysis is performed to assess the quality of the studies obtained through SLR. Further, a questionnaire intended for industrial survey was prepared from the gathered literature and distributed to practitioners from the software industry in order to collect empirical information about this study. Thereafter, data obtained from industrial survey was analyzed using statistical analysis and chi-square significance test.

Results: 20 studies were identified through SLR, which are relevant to this study. After analyzing the obtained studies, the list of RE process factors, organizational factors, challenges and RE practices during alignment between RE and V&V are gathered. Thereupon, an industrial survey is conducted from the obtained literature, which has obtained 48 responses. Alignment between RE and V&V possess an impact of RE process factors and organizational factors and this is also mentioned by the respondents of the survey. Moreover, this study finds an additional RE process factors and organizational factors during the alignment between RE and V&V, besides their impact. Another contribution is, addressing the unaddressed challenges by RE practices obtained through the literature. Additionally, validation of categorized RE practices with respect to their requirement phases is carried out.

Conclusions: To conclude, the obtained results from this study will benefit practitioners for capturing more insight towards the alignment between RE and V&V. This study identified the impact of RE process factors and organizational factors during the alignment between RE and V&V along with the importance of challenges faced during the alignment between RE and V&V. This study also addressed the unaddressed challenges by RE practices obtained through literature. Respondents of the survey believe that many RE process and organizational factors have negative impact on the alignment between RE and V&V based on the size of an organization. In addition to this, validation of results for applying RE practices at different requirement phases is toted through survey. Practitioners can identify the benefits from this research and researchers can extend this study to remaining alignment practices.

Keywords: Requirements, verification, validation, alignment, factors, requirements engineering.

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1 INTRODCUTION

Requirements Engineering (RE) and Verification and Validation (V&V) are treated inspirable and together enable successful project's development and deployment [1]. Both competences should be activated as early as possible and to support the development of products in meeting customer's expectations regarding the products quality and functionality[1][2]. However, this quality can be achieved by aligning RE and V&V and their activities[2]. Development activities between initial definition of requirements and acceptance testing of the final product are supported while RE and V&V are aligned [3].

In large scale software development, weak co-ordination between RE and V&V can lead to ineffective development, quality problems and delays functionality of the software[2][4]. For instance, if requirements changes are made without involvement of testers and without updating the requirements specification documentation, then the changed software functionality is either incorrectly verified or not verified. The weak alignment of RE also poses a possibility risk of producing a product that does not matches business or clients expectations [5]. In particular, Sabaliauskaite et al. mentioned that weak alignment between RE and V&V may affect the later project phases that may lead to number of problems such as additional cost and effort required for removing defects, non-verifiable requirements and lower product quality[6]. Furthermore, Grechanik et al.[7] identified uncertain test coverage, lack of established communication channels and not knowing whether changes made to the behavior of software are the other three alignment related problems found to affect non-dependent testing teams.

There is a substantial body of knowledge for the RE and V&V research fields. However, only a handful of studies discussed the alignment between these two areas[8]. Among them, Kukkanen et al. provided example activities that improve the alignment involving testers participating in requirements and planning test cases in parallel to the requirement analysis[9]. Some benefits of good RE and V&V alignment include[9]

- If activities of the testing were properly taken into account, domain and system knowledge will be improved.
- Requirements quality will be improved.
- During the development and testing process, communication between testers and requirement analysts will be increased which results in reducing assumptions made by testers.

Kukkanen et al. focused on concurrently improving the requirements and the testing processes[9]. Uusitalo et al. focused on identification of a set of practices used in software industry for linking requirements and testing in outsourced development[10]. In spite of the identified practices, they have also discussed interdependencies of the practices and linking people vs. linking documents along with benefits such as having testing personal in early stages improves the quality of requirements, improved test coverage etc. Furthermore, Cheng and Attlee[11] highlighted RE alignment as a focus area for further research in RE for outsourced development.

Watkins et al. and Barmi et al. considered traceability as a focal point of the RE and V&V alignment[12][8]. Traceability mainly focuses on tracing requirements with the test cases, structuring and organization of different related artefacts, performing impact analysis of requirements changes etc. [2]. But RE and V&V alignment covers the interaction between the roles that are participating in each phase along with traceability[6][2]. Sabaliauskaite et al. identified challenges in aligning requirements engineering and verification and categorized these challenges as people, organization and processes, tools, requirements process, change management, testing process, traceability and measurement[6].

In the same vein, Bjarnason et al. conducted a case study to investigate the challenges of RE and V&V alignment, identified different methods and practices used by industry to address these challenges [2]. In total 27 practices were identified and grouped them into 10 categories in order to address these challenges. Interestingly, Wnuk et al. reported from a case study that a large company significantly downplayed requirement engineering activities while shifting the focus to testing and QA activities rather than RE and testing[1]. They discussed about the impact of enabling factors such as focus on informal and direct communication, open culture to success of the company while downplaying the RE activities[1]. This study also calls for investigating and exploring which additional factors may influence the balance between RE and V&V[1].

Therefore, this thesis focuses on further exploring the additional factors that affect the alignment between RE and V&V, and the balance between them. This research is initiated with an aim to provide the practitioner's a clear idea about the influence of additional factors that affect balance during the alignment. By providing additional factors, it can further motivate focusing on the alignment between RE and V&V.

The additional factors specific to RE process and organizational factors are identified. This study also puts emphasis on the practices that facilitate the alignment between RE and V&V. These practices are applied for addressing the challenges during the alignment of RE and V&V. Due to the time constraint of the thesis, only RE practices would be considered. This in whole helps the organizations to know the suitable RE practices applied for addressing different challenges during the alignment between RE and V&V.

A systematic literature review (SLR) was conducted in order to identify the list of RE practices that facilitate the alignment between RE and V&V along with challenges faced during the alignment, RE process factors and organizational factors that influence the alignment between RE and V&V. Thereupon, the identified practices, challenges and additional factors are further explored in a survey to validate, classify them based on the level of importance.

The thesis is organized using the following sections. Section 2 focuses on providing the necessary theoretical background regarding the RE practices, challenges, impact of different factors during the alignment of RE and V&V along with research questions and objectives. Section 3 provides the research design, the research methodology used in this research and the process of SLR conduction. Section 4 explains the results obtained from the SLR and the analysis of those results. Section 5 provides the information about the survey, preparation of questionnaire, conduction of survey, overview of the respondents and the results of the survey. Section 6 provides the discussions on both SLR and survey results. Section 7 provides the conclusions for this study. Section 8 provides the future work of this study.

2 RELATED WORK

RE and V&V are the software engineering fields, which have primarily been explored with an attention on one or two other fields[8], though there are a few studies exploring the alignment between these two fields. Barmi et al. identified that the majority of the research in the field of alignment between requirements specification and testing is on model-based testing (MBT) including various formal methods for initializing requirements with models for the generation of test cases[8]. They also found that traceability and empirical studies into RE and V&V alignment practices and challenges as the fundamental fields of research. In this mapping study only 3 empirical studies were found and two of these studies were originated from the same research group and the other research group identified the challenges faced by large scale company during the alignment [8].

Damian et al. [13] explored the impact of RE on software development processes. They have found that testing has positive effects by improving RE and the involvement in terms of increased testing involvement in requirement engineering activities. In particular, they have found the sophisticated change control process brought the functional organization and organizational responsibility together through horizontal (designers, developers, testers and documenters) and vertical (team leads, engineers, executive management and technical managers) alignment of these roles[13]. Furthermore, Damian et al.[3] in another study found that high relations between RE activities and V&V can accelerate reduction in waste, over scoping and requirements creep, and also façade to improvement in test coverage and risk management, which resulted in increasing the quality of the product and productivity as well.

Thereafter, in a case study Kukkanen et al.[9] investigated the process of jointly developing the RE and testing for improved customer satisfaction and product quality in the safety critical domain[9]. They also reported that integration of requirements and testing processes by clearly mentioning requirements and testing roles, improves by connecting people and processes from RE and testing, and this can also improved by applying good practices that support connection between RE and testing[9]. The suggested relations between requirements process and testing can be observed in the Figure 1.

Change management process, the use of metrics, traceability with tool support, reviews of requirements, test cases and traces between them are the practices followed by Kukkanen et al. to support RE and V&V alignment [9]. Successful alignment between RE and testing can be assured by connecting and assigning roles from two fields as compelled for assuring the conduction of reviews. At the same time, the risk of overlying activities and roles between these two fields and the difference in the process should be minimalized by improving RE and testing processes concurrently[9]. Another case study is conducted to link functional requirements and software verification, in which results indicates that requirement management and software implementation quality will benefit greatly by aligning requirements and software verification[14]. In a case study Uusitalo et al.[10] reported alignment practices such as early tester participation, considering feature request from testers etc. that improve the link between requirements and testing along with the interaction and communication of different roles.

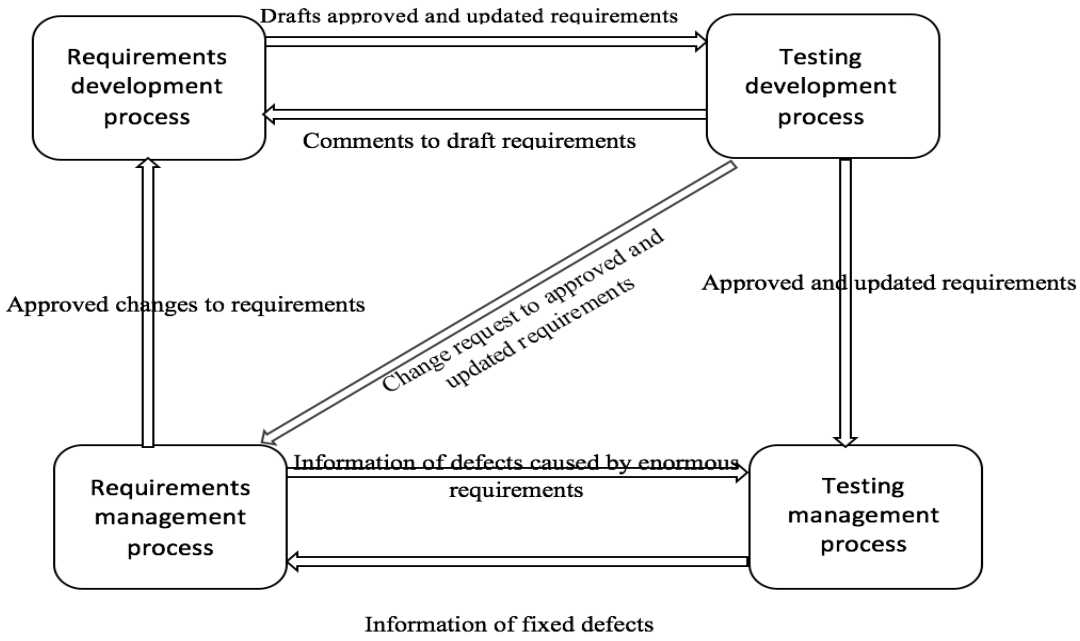


Figure 1: Relation between requirement process and testing [8]

Thereafter, Bjarnason et al.[6] conducted a multi case study in six companies to investigate the challenges of RE and V&V alignment and identified different methods and 27 practices namely early verification start, process enforcement, traceability responsibility role etc. to address the issues faced by these industries. The concepts used during the identification of these challenges, practices and methods are defined by a conceptual model. This conceptual model is identified on the basis of V-model that shows artefacts and processes which were covered during this multi-case study, including relationship between artefacts of different abstraction levels, see Figure 2 [2].

In another study Bjarnason et al.[15], proposed a model for alignment of RE and V&V that involves early V&V to reduce the cost and improve the quality of the requirements. This model also helps in identifying errors in early stages and making requirements generation process more cost effective and quality focused. Unterkalmsteiner et al. [16] proposed a definition for alignment between requirement engineering and software testing (REST).They also proposed a taxonomy that describe the methods linking RE and testing areas and processes to determine the alignment along with the emphasis of traceability during RE and V&V alignment.

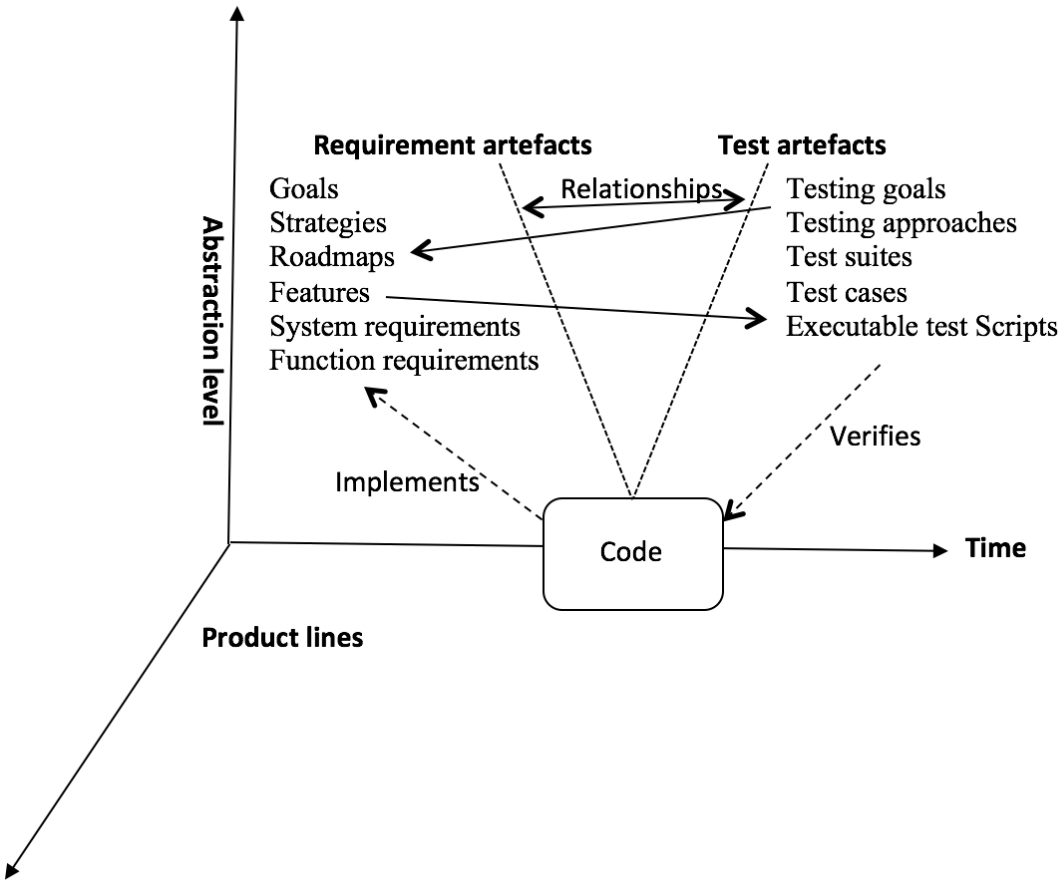


Figure 2: The conceptual model [2], [6]

Traceability was extensively discussed from the birth of software engineering[19]. Lower testing and maintaining costs, increased test coverage and quality in the final output of the product can be supported by traceability between requirements and other development artefacts[9][10][12]. Tracing between artefacts is also essential for V&V as it helps in increasing the quality of software[12]. Challenges such as communication gaps, lack of training, volatility of the traced artefacts etc. related to traceability are reported and empirically investigated from many years[2][20]. Gotel and Finkelstein concluded that informal communication between persons responsible for requirement specification and detailing requirements will improve the traceability [21]. Ramesh et al.[22] advocated that requirements traceability is influenced by three factors, namely environmental tools, organization (internal or external organization incentives) and development context (practices and process). However, Unterkalmsteiner et al.[16] mentioned that high quality traces are expensive, but their contribution can improve the alignment and it is not only solution to achieve the alignment.

Many formal models and languages were suggested for representing requirements for model based testing (MBT) [23]. MBT struggles[24] with practical applicability of traceability in industrial development[25][26]. However, Nebut et al. [25] and Hasling et al[27] reported that applying MBT by generating test cases from UML description of requirements benefits in increasing test coverage and testing productivity. The conversion of technical requirements into a formal model could encounter some of the difficulties such as requiring special competence to produce requirements etc. [25]. Therefore, Yue et al. stated that additional research is needed before proposing a practical solution to this conversion of technical

requirements[26]. Automated test case generation of test cases generation has the potential of linking requirements without any creation or maintenance of manual traces [2]. However, the value of the traces may vary by depending on the generated test cases and the abstraction level of the formal model[6]. While applying MBT, error causes in these formal models are the main hindrance to fully trust them [27]. As an alternative to formal models scenario-based models are defined such as user stories, use cases [28] [29] to cover requirements. In scenario based models acceptance test cases are used to document the detailed requirements at a high level and this approach is often applied in agile development by Cao and Ramesh [30]. In another study Melnik et al.[31] found that to implement and feather testing mentality, executable acceptance test cases can be used as detailed requirements.

During the alignment between RE and V&V many authors stressed the importance and impact of various factors such as RE process factors, contextual factors, organizational factors, V&V factors etc. Bjarnason et al. [17] discussed the impact of process factors, while performing a case study to find the benefits and challenges in using test cases for elicitation, validating, verifying, tracing and managing requirements. During this study they have discussed the consideration of process factors i.e. source of requirements, requirements in typical project. In a similar study to this, Kukkanen et al.[9] stressed to know the importance of process factors which may shorten the development time and improve the quality. In another study, Sabaliauskaite et al. [6] discussed the influence of organizational factors i.e. organizational structure, gaps in communication across different organizational units, however without details. Similarly, Bjarnason et al.[18] discussed influence of organizational factors during a study to present an initial version of a theory based on the GAP model. During this study they have discussed the organizational factors that influence the alignment i.e. size of an organization, domain and range of an organization. Whereas, Wnuk et al. [1] discussed the impact of enabling factors such as focus on informal and direct communication, open culture for the success of a software project.

However, for achieving RE and V&V alignment, many companies with strong incentives apply alignment to disguise challenges including full traceability between requirements and testing [6]. This clearly depicts that the requirement of aligning artefacts along with few more factors. In addition to this, in other study Wnuk et al. [1] calls for investigating and exploring of additional factors that may influence the balance between RE and V&V. Further, there are very few studies which focuses on impact of RE process factors and organizational factors and very handful number of studies has discussed addressing RE and V&V alignment challenges with well suited alignment RE practices. Therefore, this study fills this gap by investigating the impact of all the RE process factors and organizational factors found in literature and verify with the industries along with RE practices addressing different alignment challenges.

2.1 Aim and objectives

AIM: To identify the impact of RE process factors and organizational factors during the alignment between RE and V&V.

OBJECTIVES:

- O1: To identify requirements engineering practices that facilitate RE and V&V alignment[2].
- O2: To categorize the obtained RE practices with respect to their requirement phases.
- O3: To identify RE process factors that influence RE and V&V alignment.
- O4: To identify organizational factors that influence RE and V&V alignment.

- O5: To identify challenges that are faced during the alignment between RE and V&V.
- O6: To identify challenges that are addressed by RE practices during the alignment [2].

2.2 Research questions

As mentioned in section 1, the first step of this thesis is to find the RE practices, RE process factors and organizational factors that influence the alignment between RE and V&V. Therefore, research questions are formulated in such a way to gather all related literature from systematic literature review and these results are validated through survey.

RQ1: What RE practices that facilitate alignment between RE and V&V?
RQ 1.1: In which requirement phases does the identified RE practices are applied?

RE Practices that facilitate alignment between RE and V&V will be identified through a systematic literature study. These identified practices are used to address the required challenges identified through RQ4. Further, a survey is conducted to validate and identify any additional RE practices, which were not gathered through literature.

RQ2: What RE process factors influence the alignment between RE and V&V?

RE process factors that influence the alignment between RE and V&V will be identified through a SLR. The influence of these identified factors is further validated in a survey, along with identifying any additional RE process factors.

RQ3: What organizational factors influence the alignment between RE and V&V?

Organizational factors that influence the alignment between RE and V&V will be identified through SLR. The influence of these identified factors is further validated in a survey, along with identifying any additional organizational factors.

RQ4: What are the challenges faced during the alignment between RE and V&V?
RQ4.1: What challenges can be addressed while applying RE practices?

RE practice gathered as a part of answering RQ1 will provide a summary of RE practices that facilitate alignment between RE and V&V. To identify the challenges that are addressed by RE practices, a SLR is performed. During this process SLR identifies the alignment challenges. Further, the identified challenges are validated through a survey along with knowing the most occurred challenges during alignment between RE and V&V.

3 RESEARCH METHODOLOGY

Appropriate research methodology techniques should be selected to achieve the objectives of this research and to answer the research questions. The author conducted a careful analysis of the available research methods and decided to perform the survey and the systematic literature review through snowballing procedure. The research plan was selected in a way to collect and analyze qualitative data by conducting SLR, which was followed by the collection and analysis of the qualitative form of data by conducting survey [32]. Figure 3 provides an overview on sequence of steps in research design.

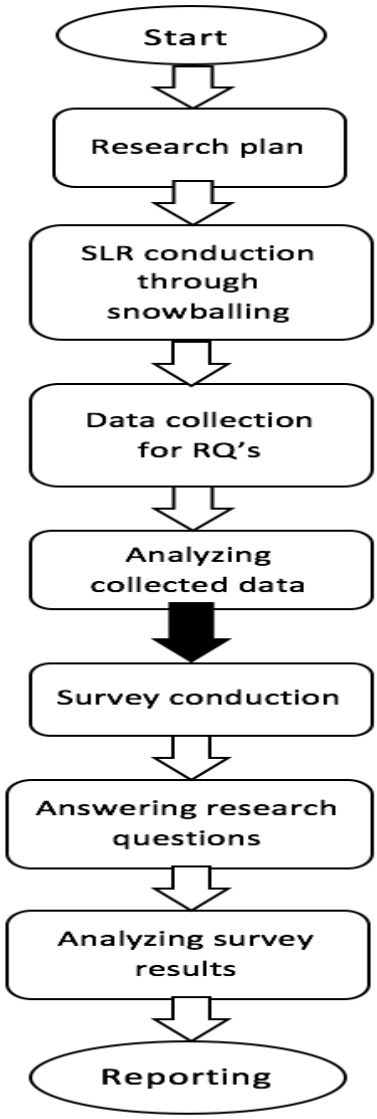


Figure 3: Research design overview

3.1 Systematic Literature Review

It is important to know that planning of SLR is independent of the search approach [32]. In this research snowballing is opted as a search approach over database search. In the following, author explained why database search was not chosen along with advantages for using the snowballing procedure.

Why not a database search?

The reason for not choosing database search is due to fact that, it is quite difficult to formulate a good search strings. Since, the terminology used for the formulation of search strings is not standardized and if it is extended to capture the data in a broader perspective, then there might be a chance for finding large number of irrelevant papers in the search [33] [34] [35]. Moreover, it creates generous manual work, which also is an error-prone [33]. Wohlin [33] mentioned about the challenges with database searches such as constructing search string in different ways, databases selection, different interfaces for databases, usage of different search limitations and identification of synonyms for terms, which can lead to missing of important literature. Wohlin [33] also explains the difficulties with inconsistency in terminology by using an example. The results of an example in [33] show that while using the guidelines with the formulation of search string in database search some relevant papers are not caught. Whereas, using snowballing procedure these papers were caught. Thus snowballing was considered as a search approach by following the guidelines of Wohlin [33].

However, Systematic-mapping study can be considered as the secondary/alternative research type for performing this research. By using systematic mapping study, available literature on a specific topic can be summarized. This kind of research method can be used when the scope of the research area is extensive and broad. However, in systematic mapping obtained results are ad hoc and they cannot be referred as evidence based. Therefore, a snowballing procedure is elected as a primary method instead of systematic mapping and traditional literature review can also be considered. However, snowballing can identify valid and reliable data, but by using traditional literature review it might not be possible, as it does not contain any sequence of steps for quality assessment and data analysis. Also, the list of objectives will not be provided in survey, this makes it need for identification of valid and relevant data of high quality, which is possible only using SLR.

Search approach: snowballing as a search approach

The importance of systematic approaches for building knowledge from the literature is stressed by several authors, including information systems researchers e.g. by Webster and Watson [36], evidence based software engineering scholars, e.g. Kitchenham et al. [37]. Moreover, Hayes [38] and Miller [39] addresses the issues regarding the combining research results through metadata analysis.

Wohlin [33] clearly mentioned that snowballing can be used as a search approach for systematic literature studies by complementing the previous guidelines for systematic literature review in software engineering studies. Here, systematic literature studies were used as a collective term for both SLR and systematic mapping studies [33]. Snowballing can also be used as a reference for identification of additional list of studies through citations and references of selected studies[33]. However, snowballing procedure can benefit from systematic way of looking at venues of papers and who cites them and where papers are referenced rather than looking at the citations and the reference lists [33]. Using the citations and references respectively corresponds to forward and backward snowballing. These snowballing guidelines are introduced by Wohlin and illustrated by simulating a published reliability study of SLR [33].

However, by this evolution it is clearly confirmed that using snowballing as the main approach is good against the database search in terms of efficiency. The main advantage of snowballing is reduced noise compared to database searches due to focus on papers actually referenced or citied. Also, snowballing was proven to be appropriate for extending previous systematic literature reviews.

Why Google scholar was not chosen for start set:

Wohlin suggested using google scholar for the identification of start set identification [33]. Google scholar was used to avoid publisher bias. However, Google scholar lacks in providing certainty in terms of scholarly value and currency of some records, lacks in including the scope of its coverage [40]. From the observations of Google scholar disadvantages, it was observed that experts in particular domain can easily pick up the good start set of papers, but it does not seem easy for everyone. In the experimental study, the results of tentative start set of papers are far perfect from the actual papers but the resulted start set had same author in common of all papers [33]. However, no action was taken since Wohlin used research question from the original study [33]. To mitigate this kind of risk, author has taken researchers point of view into the observation on particular selected studies.
However the results in the experimentation by Wohlin [33] showed that snowballing could be used as a database search in terms of efficiency. This is the main motivation behind choosing snowballing as a search approach for SLR with a change in database.

Why engineering village was selected as database search instead of Google scholar:

In this study for selecting tentative start set of papers "Engineering village" database was opted. Kinsely et al. compared databases and search engines for engineering information referencing with the fusion of published results by the librarians and concluded that, "Engineering village" as an ideal place to initiate an engineering search when compared to other databases [40]. Google scholar turned out to have many disadvantages such as, when including the scope of coverage of a study it finds too much of information, uncertainty about currency of some of the records and scholarly value [40]. In this study Google scholar is not chosen, since this particular study focus and goals are narrow. This clearly shows that this study needs more consistency and scope of finding relevant articles, which clearly defines the selection of "Engineering village" over Google scholar.

3.2 Snowballing Procedure

As per the guidelines of Wohlin[33] the snowballing method involves two different steps:

1. Identification of Start set.
2. Performing backward and forward snowballing in iterations.

3.2.1 Identification of start set

In the first step, the keywords were identified and formulated into a search string to identify set of papers to be used for the snowballing procedure. Any search for related papers to include in a start set gives a tentative start set [33]. The actual start set has only papers in tentative start set. According to Wohlin[33] , good start set has the following characteristics:

- Studies that were published from different communities, years, publishers and authors.
- Size of the start set or number of papers in start set depends on the breadth of the area being covered/studied.

- A start set ought to be formulated by preferably taking synonyms into the account from the keywords in the research question. This mitigates the risk of only capturing papers using only scientific terminology.
- To attain a good start set, consideration of number of relevant studies and highly cited articles is an alternative method, since start set finds too many papers due to general search string.

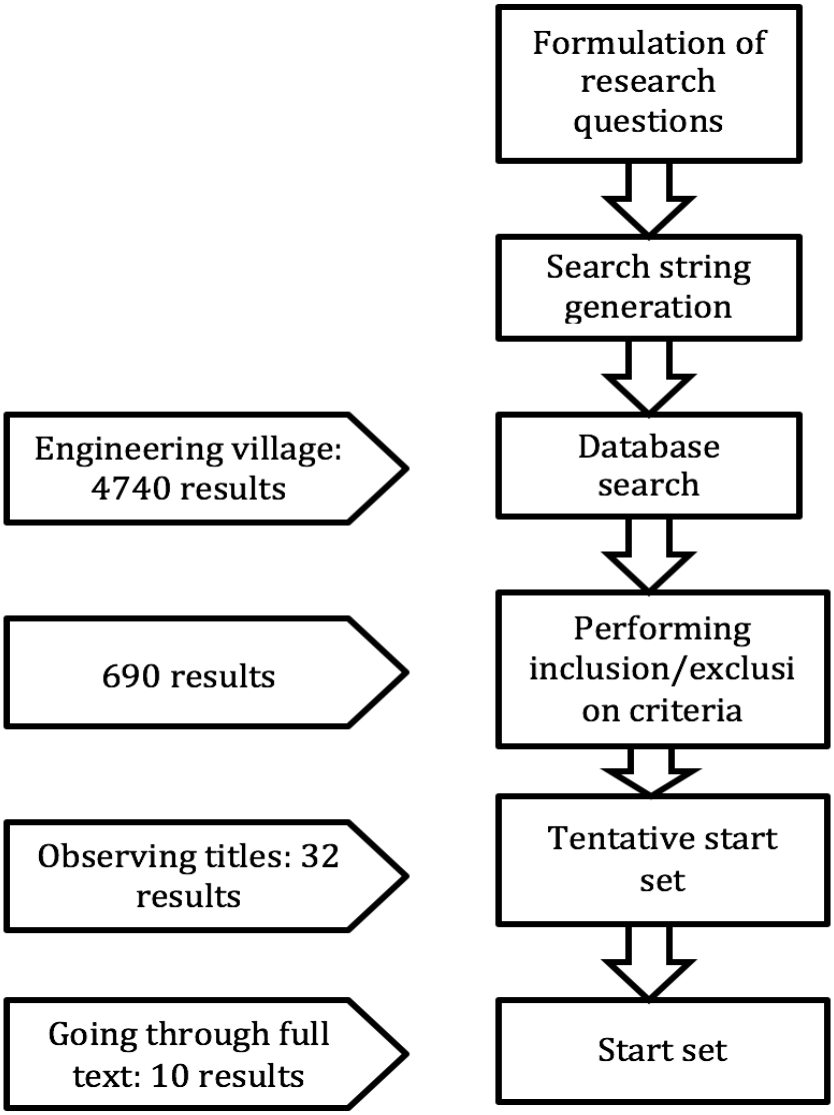


Figure 4 Steps for start set identification

Search string and database selection:

To obtain a search string we should get some overview on requirements and verification & validation areas and their alignment. From the research questions and based on the study of initial set of papers, author derived some categories of search terms. These categories focus on Non-functional requirements (F1), Requirements (F2), verification and validation (F3) and

alignment(F4). Search string formulated by using these categories is “F1 OR F2 AND F3 AND F4”.

Table 1 Search keywords

Keyword category	Alternative keywords
F1: non-functional requirements	"nonfunctional requirement" OR "nonfunctional requirements" OR "non functional requirement" OR "non functional requirements" OR "non functional software requirement" OR "non functional software requirements" OR "nonbehavioral requirement" OR "nonbehavioral requirements" OR "non behavioral requirement" OR "non behavioral requirements" OR "non behavioural requirement" OR "non behavioural requirements" OR "nonfunctional property" OR "nonfunctional properties" OR "non functional property" OR "non functional properties" OR "quality attribute" OR "quality attributes" OR "quality requirement" OR "quality requirements" OR "quality attribute requirement"
F2: Requirements	“Requirements”
F3: Verification and Validation	"test" OR "tests" OR "testing" OR "verify" OR "verifying" OR "verification" OR "validate" OR "validation"
F4: alignment	"align" OR "aligning" OR "alignment" OR "trace" OR "tracing" OR "traceable" OR "traceability" OR "link" OR "linking" OR "links" OR "bridge"

Database selection is the next step after the search string formulation. Engineering village was selected for identifying the start set instead of Google scholar. The reasons for selecting Engineering Village are discussed in section 3.1. Start set is identified in the following sequence of steps.

1. Extraction of studies from database using a search string: 4740 papers were identified.
2. By considering the papers only in between 2002-2016: 3223 papers were identified.
3. By considering the inclusion and exclusion criteria, ended up in getting overall 690 results.
4. From these 690 results by observing the titles 658 papers were not found relevant and excluded. Remaining 32 candidates are considered as a tentative start set.
5. From these 32 results only 10 results are considered for the start set by reading the full text.

The above search string covers the entire alignment between RE and V&V unlike just RE

practices, RE process factors, organizational factors and challenges faced during alignment between RE and V&V. Initial idea of the author is to capture the verification and validation practices along with RE practices that are followed during the RE and V&V alignment. However, due to time constraint of the thesis only RE practices are identified. Therefore, search string is formulated in a way to cover the entire RE and V&V alignment area. Barmi et al. [8] mentioned that research on alignment between RE and testing was started from the end of year 2001, this motivates the author in selecting studies from 2002.

Tentative start set selection:

Precautions were taken by excluding duplicate authors by keeping the characteristics of good start set in mind. This is due to authors citing his/her papers in the specific area are so obvious and these papers will be obtained through snowballing. After implantation of inclusion/exclusion criteria 690 results were obtained. From these 690 candidates only 32 candidates are considered for the tentative start set by looking after titles. The inclusion and exclusion criteria's were derived and outlined in the following way. These inclusion and exclusion criteria were applied on studies simultaneously to make sure that, we have included the studies that contain software engineering domain and excluded studies contain such as management, biology or history. Table 2 illustrates the inclusion and exclusion criteria for this study.

Table 2: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
IC1: Studies must be available in full text. IC2: Studies must be available in English language. IC3: Studies should be peer reviewed. IC4: Studies that have any type of alignment related to requirements and V&V should be included. IC5: Studies related to formal methods, software engineering techniques and Diagnostic, testing and debugging method classification codes are included. IC6: Conferences, journals, articles that are published in between 2002-2015 years are included [8]. IC7: Factors influencing the alignment study IC8: The study that reports the benefits, challenges, disadvantages, practices of alignment study.	EC1: The studies that contain alignment keywords but not related to requirements and testing are excluded. EC2: Any alignment study available in language other than English will be excluded. EC3: Any alignment study that does not reflect any research type will be excluded. EC4: The studies, which are not available in full text, will be excluded. EC5: All grey and white literature. EC6: All duplicate studies.

Start set selection:

If there are any papers that cannot be decided by looking at abstract and conclusion, then the author went through the full text and made the decision. After reading full text of each paper for

the start set, only 10 candidates were selected out of 32 candidates. Important issue during the identification of start set is targeting diversity. Therefore, after reading full text papers that have more citations and references are included over papers with less number of citations and references. This assists in achieving the possibility of more coverage of relevant studies [33].

3.2.2 Forward and backward snowballing in iterations

For the resulting tentative start set backward and forward snowballing was applied from step 1. This resulted in two iterations. Foremost, backward snowballing is applied by looking into the references of the selected papers and also by following inclusion/exclusion criteria. Then forward snowballing is applied for the citations of each paper. To identify the citations of each paper Google scholar was used. For forward and backward snowballing the inclusion and exclusion criteria remained unchanged.
Final paper inclusion should be based on the full paper read, i.e. before the paper can be included in a new set of papers that goes into the snowballing procedure. Iteration should be done until no papers were found. If no papers were found, then the snowballing procedure is finished. Figure 5 shows snowballing steps.

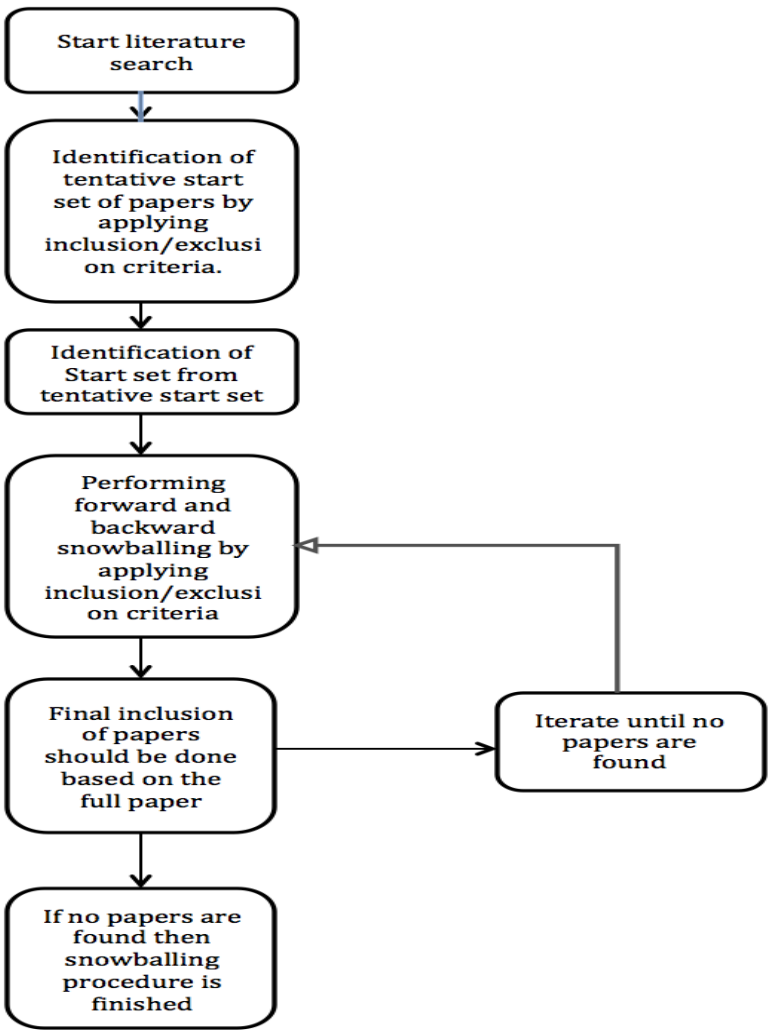


Figure 5: Snowballing procedure steps

3.3 Data extraction and synthesis

Data extraction properties were created in spreadsheets and also mapped with research questions and finalized and discussed before the application. These data extraction properties are outlined in the Table 3. Rigor and relevance criterion was used to check the trustworthiness of each paper. This helps in identifying weather the results suitable for the identification of practices, challenges and influencing factors in alignment study.

Table 3 Data extraction properties mapped to research questions

Category	Properties	RQ mapping
General information	Authors Title Year of publication Abstract	RQ1, RQ2, RQ3, RQ4
Study type	Proposal of solution Evaluation research Validation research Philosophical papers Opinion papers Personal experience papers	RQ1, RQ2,RQ3, RQ4
Research methods	Case study Experiment Survey Framework	RQ1, RQ4
Research problem	i. Does the study specify the RE practices during alignment between RE and V&V? ii. Does the study specify the specific RE process factors? iii. Does the study specify the specific organizational factors? iv. Does the study specify the challenges that are faced during the alignment between RE and V&V?	i. RQ1, RQ1.1 ii. RQ2 iii. RQ3 iv. RQ4, RQ4.1
Outcomes	i. Practices during alignment between RE and V&V ii. Influence of factors iii. Challenges	RQ1, RQ 1.1 RQ2, RQ3 RQ4, RQ 4.1

3.4 Narrative analysis

For analyzing the results obtained through literature, narrative analysis was used. Narrative analysis is defined as "*an approach to the systematic review and synthesis of findings from multiple studies that relies primarily on the use of words and text to summarize and explain findings of the synthesis*" [41]. This approach helps in process of explaining the data retrieved from the identified studies[41] in a 'tell the story' way. This also used to synthesis the data that can be used in the identified studies, which were focused on a wide range of research questions, not only studies related to the effectiveness of a particular research area [41].

3.5 Quality assessment through rigor and relevance

Quality assessment criterion is conducted for the final set of papers obtained after the completion of snowballing procedure. Rigor and relevance assessment is applied for the studies to assess the trustworthiness. The assessment is accordance to the checklist provided by Ivarsson et.al [42].
The checklists for rigor and relevance proposed by Ivarsson et al. [42] can be seen in appendix D.

3.6 SLR validity threats

In this section, the possible validity threats in the SLR part of the work and their mitigation strategies to those threats are provided.

3.6.1 Construct validity

In the snowballing study, construct validity refers to the information relevant to alignment between RE and V&V and the presence of confounding factors whether or not this study capable to capture its aims and objectives. Construct validity threats were reduced by detailing the section and planning according to the formulated research questions. One of the main threats for using snowballing approach for SLR is obtaining a good start set. Using the guidelines suggested by Wohlin[31] for obtaining a good start set such as, design of start set is extended with the change in database selection is followed. This mitigates the risk of obtaining irrelevant studies. Moreover, to mitigate the risk of resulting same author, some authors are excluded during the selection of start set of papers. Finally, the thesis supervisor was involved in the start set selection and snowballing iterations to ensure that the inclusion decisions are fully justified and uncertainties are resolved.

3.6.2 Internal validity

Since the author does the study selection, internal validity is one of the major challenges for systematic literature review part of this study. This is mitigated by being broad as possible and verifying with a supervisor whenever there is a doubt. Another threat can be when deciding which articles to exclude or include, because finding the RE process factors, organizational factors related to the alignment between RE and V&V is challenging, which is not very straight forward question in most of the literature, this can lead to the risk of skipping or overlooking of useful articles. By the involvement of supervisor reviewing each iteration for obtaining start set of papers and four iterations of snowballing procedure helped in mitigating this risk. By strictly following the guidelines for snowballing procedure and for quality assessment criteria[33] the internal validity for this study is enhanced.

3.6.3 External validity

The ability to generalize the results to different groups, situations and settings is referred as external validity. The majority of the studies resulted are case studies (10) with high rigor and relevance. This shows that the results are more relevant to industrial context and this gives more ability to generalize the relevant information. To increase the external validity, start set for snowballing procedure was composed from a database search with Engineering Village selected as a source that has a broad range of engineering conference and journal publications.

3.6.4 Reliability

"To what extent the data and the analysis are dependent to a specific researcher" is concerned as reliability [43]. Reliability of this study is enhanced by mitigating the risk of missing relevant studies with a single search string. Therefore, 4 studies related to alignment between RE and V&V (that were included in start set) were identified through forward snowballing to verify the accuracy and the strength of search string. However, this benefits in minimizing the selection bias, which might have impact on further steps of this research. Furthermore, backward and forward snowballing was carried out and resulted in attaining relevant studies of RE and V&V alignment. Moreover, the thesis supervisor was involved in the start set selection and snowballing iterations to ensure that the inclusion decisions are fully justified and uncertainties are resolved.
Thereafter, objectives of this research study were compiled by mapping identified research questions with data extraction properties as mentioned in Table 3, in a data spread sheet. These data extraction properties were reviewed by both the author and supervisor. Moreover, quality of the identified studies is an important objective since this research focuses on factors and practices related to industry. Therefore, quality assessment is carried out by applying the rigor and relevance assessment criteria suggested by Ivarsson and Groschek[42].

3.7 Industrial Survey

An industrial survey is performed using the RE process factors, organizational factors, challenges and RE practices during the alignment between RE and V&V, that were obtained from the SLR results. The survey was used to understand the impact of RE process factors and organizational factors during the alignment between RE and V&V, which is one of the important aspect of this research. This survey was used to gain knowledge about the aspects that were not covered in the literature such as use of RE practices addressing different challenges.

3.7.1 Methodology validation

To empirically perform the research there are different methods exists such as case studies, experiments and interviews[44].
Due to time and resource limitations the case study method was not considered for this research. In this research in order to perform a case study, the author has to study the case of an organization for a specific period of time, while they were implementing the alignment practices during the alignment between RE and V&V. This implementation of practices might take few months of time and since the time constraint of this research is limited, for this study, case study was not considered. Also, in a case study the obtained results might be specific to particular project or the organization where the research was performed. Since the

results of this research can be applicable to a generic body of practitioners applying alignment practices, case study was ruled out. For this research, experiments were also not considered. Since experiments are meant to deal with studying the situation of a controlled scenario [44], this idea of creating a scenario might not depict a generic organizational situation. Therefore, for this research study experiment was not considered.
Therefore, in this research a survey method was used. Creswell states that a survey provides a "quantitative description of trends, opinions or attitudes by studying a sample of population" [44]. In this research, with the help of a formalized questionnaire a structured survey was conducted [45].
Malhotra et al. specified that survey can be conducted in different types of approaches such as phone survey, personal survey, mail and electronic survey[45]. Mail and electronic media survey were used in this research. The main reason for selecting an electronic survey is to gather the responses on a larger scale of respondents and participants who works in different organization around the different parts of the globe. Electronic surveys help in accessing the large number of respondents, takes less amount of time to prepare and publish, collected data can be easily analyzed and managed. The questionnaire was prepared using an online tool survio, which is an easy tool for the preparation of questionnaire and analysis of data.

3.7.2 Survey Planning and Execution

The process of conducting a survey is broken into the following sequence of steps: Planning the survey, designing the survey and execution of the survey. Survey planning stage consists of objective definition, survey scheduling and planning the resources that are needed for the survey. Survey design consists of construction of the questionnaire, validation of the questionnaire and sample selection. Survey execution consists of collection of responses, processing and reporting the results. In the figure 6, steps needed for performing the survey are provided.

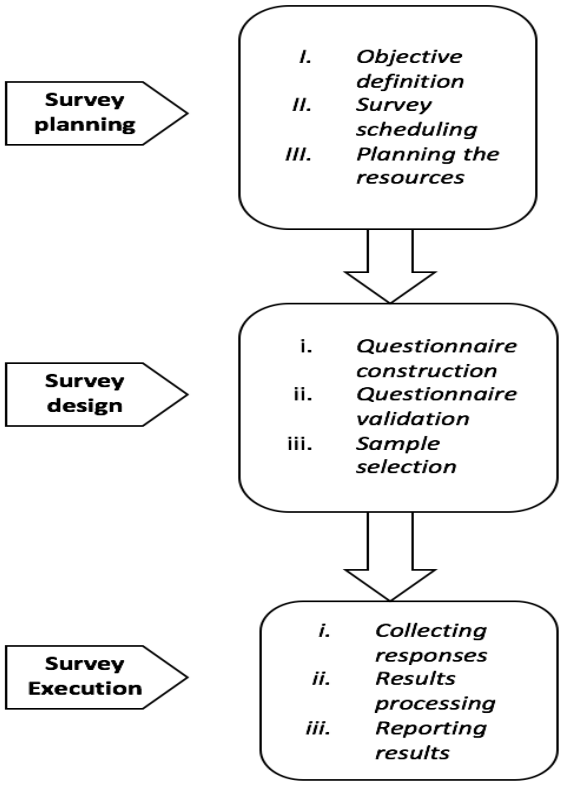


Figure 6 Steps followed to perform survey

3.7.2.1 Planning the Survey

Objectives of the survey: The objectives of the survey should be identified beforehand. This identification helps in identifying the scope of the survey and also, helps to define respondents sample to obtain the relevant data. The objectives of this survey is based on the RQ's of this research. They are

- To identify the impact of the already identified RE process factors and additional RE process factors during the alignment between RE and V&V.
- To identify the impact of the already identified organizational factors and additional organizational factors during the alignment between RE and V&V.
- To validate the RE practices that address different set of challenges.
- To obtain the application of RE practices during requirement phases.
- To identify the challenges that are faced mostly during the alignment between RE and V&V.

Scheduling the Survey: The survey was scheduled for four weeks. This specific time frame was chosen based on the results of the SLR and time constraint of this thesis.

Planning the resources: Online survey was utilized in order to extend the reach of the questionnaire to all software practitioners such as requirement analysts, business analysts, quality analysts etc. in applying alignment practices the resources should be identified. Therefore, social networks such as LinkedIn, Facebook and groups such as google professional groups, yahoo professional groups and websites such as www.surveymonkey.com, www.survio.com were selected for positing the questionnaire. In

addition to this, electronic mails were also sent to the individuals based on their designation e.g. requirement analysts, business analysts etc. Names and email addresses of these individuals were taken from the social network groups such as "ISTQB technical test analyst study & networking groups" in LinkedIn and professional blogs such as "Requirement Engineering- CPRE".

3.7.2.2 Survey Design and Execution

Development of the Questionnaire: Survey questionnaire was prepared in order to achieve aforementioned objectives. This questionnaire consists of both open ended and close ended questions [46]. In total, the questionnaire consists of 15 questions (see Appendix A) and divided into three parts. First part of this questionnaire consists of 3 questions related to demographics and includes size of the organization, name of the organization and location of the organization in specific to country. The questions in this part also consists of 2 questions regarding the respondent's role in his/her organization and his/her work experience within related to requirements.

The second part of the questionnaire captures the data regarding the impact of RE process factors and organizational factors during the alignment between RE and V&V. The respondents were asked to select the impact as positive, negative or neutral during the alignment between RE and V&V. In addition to that open ended questions are provided to the respondents for mentioning about additional (if any) RE process factors, organizational factors and their impact during the alignment between RE and V&V.

The third part of the questionnaire captures the data regarding the challenges that are faced, practices that are employed to address these challenges and RE practices applied at the different requirement phases during the alignment between RE and V&V. The respondents were asked to select the level at which the challenges occur, the RE practices are applied at different requirement phases and to match the practices with addressed challenges. In addition to that open ended questions were provided to mention additional challenges (if any) along with their level of occurrence and additional practices which were not specified in the questionnaire. As a last step, respondents were presented a text box with a question to give their email address to receive the results of the survey. The survey questionnaire is provided in the Appendix A.

Questionnaire validation: In order to check the reliability, the questionnaire must be validated. A survey cannot provide the reliable and required answers, if there is any problem with the language, context etc. for the respondents to answer it. Kitchenham and Pfleeger [47]mentioned that every survey has to be piloted to check the understandability, response rate, reliability and validity and to ensure data analysis techniques matches the expected responses.

The pilot survey has been conducted with 12 practitioners and a subject expert. The software practitioners were selected as they had previous experience with requirement engineering processes and testing. Two iterations were made to improve the understandability of the questionnaire, time taken and reliability. Table 4 shows the validation of questionnaire in iterations.

Table 4 Questionnaire validation

Criteria	Iteration 1	Iteration 2
Understandability	Respondents felt some of the questions were not	Respondents felt the questionnaire is

	understandable and there are some unrelated questions to the topic.	understandable and there are no unnecessary questions.
Number of questions	22	16
Time taken	16minutes	11minutes

Initially, 22 questions were provided in the questionnaire, which included separate questions for addressing each challenge. Respondents felt that there were some un related questions regarding the topic and length of the questionnaire was too long. Respondents suggested to reduce the length of the questionnaire and make changes in questions such as increasing interval in experience period and size of the organization. The subject expert suggested a change regarding the experience of the practitioner. Initially, it was asked as in general experience and then it was changed as experience within related to requirements. As per suggestions of the pilot respondents and expert researcher, the challenges related question is made as a matrix multiple choice question and the number of questions were reduced to 16 from 22. The questionnaire was iterated for second time, after making these suggested changes. This time respondent felt that the survey was understandable and less time taking for answering. Therefore, the final questionnaire was selected for the survey and it is provided in the appendix A.

Sample selection: Before posting the survey in the Internet, it is important to finalize the set of respondents relevant to this research topic, in order to answer it. Kitchenham and Pfleeger mentioned [47], a valid sample is a representative subset of the targeted population. The author targeted populations are the requirement analysts, test analysts, business analysts, quality analysts, test leads, team leads who are working on applying the alignment practices between RE and V&V. Probabilistic and non-probabilistic are the two sampling methods suggested by Kitchenham and Pfleeger[47]. In probabilistic sampling the members of the targeted population are known and have non-zero probability in being involved in the sample set. Whereas in non-probabilistic the respondents are chosen by choice because they can be easily accessed and researcher have some justification for believing that they are representative of the targeted population [47]. Quota sampling, snowball sampling, convenience sampling and focus groups are the methods included in non-probabilistic sampling. As the targeted population for this research is specific, non-probabilistic sampling was used. Convenience-sampling method was also used in this research, which "involves obtaining responses from those people who are willing to take part and available"[47]. Requirement analysts, test analysts, business analysts, quality analysts, test leads, team lead etc. can answer this survey.

3.8 Statistical analysis

Statistical analysis was used to analyze the results of the survey conducted for this research. Statistical analysis deals with type of the data that was collected through survey and also deals with analyzing the obtained data, depending on the variables and statistical methods [48]. For analyzing the obtained data two statistical methods such as descriptive and inferential methods can be used. Descriptive statistical method was chosen to summarize the respondents data by analyzing the results in numerically or graphically [48]. By performing statistical analysis, we can observe which RE practice is addressing which challenge with respect to each RE practice during the alignment between RE and V&V and this answers RQ4. Statistical methods used for analyzing the results of the questionnaire is described in this section and to find the significance relationships.

3.8.1 Likert Scale

Likert scale is considered for questionnaire, which is most commonly used. The agreement and disagreement of respondents is measured with a scale of three points sometimes five or seven points. The middle point of this scale is generally considered as a neutral opinion about the question or statement. The scale is generally measured from the agreement (3=important), then neutrality and then disagreement (1=not important)[49]. Data of likert scale can be considered as ordinal scale or interval scale. However, by observing the questions in the questionnaire, Likert scale is considered as an ordinal scale in this research.

Likert scale data is analyzed using descriptive analysis (mean, median, mode). Many of the statisticians suggested that suitable measure to analyze ordinal scale is through median [50]. However, many statisticians argue about drawing conclusion with the use of median with Likert scale. Many of them believe that athematic mean is more suitable for Likert scale in order to analyze the results[50], this helps in drawing better conclusions and pointing out essential data about the obtained results. Therefore, in this research, the analysis of the questions with Likert scale in questionnaire will be based on the mean (average).

3.8.2 Chi-square test of significance

To recognize statistical significance between two categorized variables chi square test of significance is used. Chi square test is "essentially concerned with the difference between the frequencies that are obtained from the sample survey and those that could be expected to be obtained if there were no difference among the categories of the variables"[50]. In other words, chi-square test can be used for calculating the statistical difference between the observed values and expected values.

In general, there are two assumptions related with chi-square test namely, *null hypothesis H0* and *alternative hypothesis H1*. Here, *H0* assumes no statistical significance (relationship) among the categories of the studied variables and *H1* assumes a statistical significance (relationship) among the categories of the studied variables.

Chi-square test is conducted using the formulae

$$X^2 = \sum \frac{(Observedvalues - Expectedvalues)^2}{Expectedvalues}$$

Critical chi-square (χ^2) value is used to decide whether to accept or reject the *null hypothesis H0* or the *alternative hypothesis H1*. Therefore, chi-square value needs the information regarding the level of confidence that the research accepts the results (95%) and degree of freedom which is "the number of cells that are free to vary" [50]. The degree of the freedom is calculated using the formulae: *df = (c-1) (r-1)*

Where *c=number of categories of the column variable*
r=number of categories of the row variable

After finding the critical chi-square value, researcher can decide weather to reject or accept the *hypothesis.* If the calculated chi-square value is less than the critical chi-square value, then the hypothesis can be rejected. Otherwise, researcher can accept the *hypothesis.* The validity of chi-square test results depends upon the considerations made by the researcher, when conducting and interpreting the results. However, for generation of chi-square test significance values an online tool SPSS version 21 was used, based on this tool considerations to accept chi-square test are: " The expected frequencies for each category should be at least 1", and "no more than 20% of the categories should have expected

frequencies of less than 5"[50](see page no. 223 in [50]). If any of these conditions were not achieved, then the chi-square results are invalid.
As mentioned previously, chi-square test of significance evaluates the existence of relationship between two variables. On the other hand, Crammer's V is used to measure the strength of the relationship[49]. This association ranges from 0 to 1 see Table 5.

$$V = \sqrt{\frac{\chi^2}{n(M-1)}}$$

Where, χ^2 =calculated chi square
n=sample size
M=minimum number of rows and columns

Table 5 Interpretations for strength of relationships[51]

Measure	Interpretation
Less than 0.10	No association
0.10-0.20	Weak
0.20-0.40	Moderate
0.40-0.60	Relatively strong
0.60-0.80	Strong
0.80-1	Very strong

3.9 Mapping between Research Questions and Research Methodology

As mentioned in section 2.2, this research intends to answer four research questions. The research methodology selected for answering these research questions is a snowballing literature study and industrial survey. Initially, snowballing literature study was conducted to obtain the literature regarding the RE process factors, Organizational factors, alignment challenges and RE practices that addresses alignment challenges. After completion of the systematic literature review, the results were analyzed. Thereafter, triangulation[52] was used to test the validity and reliability of the obtained results. Therefore, survey was used for performing triangulation to the data obtained through snowballing study. Survey also helps in finding the additional RE process factors, organizational factors and challenges faced during the alignment between RE and V&V along with validating challenges that are addressed by RE practices and use of these RE practices at different requirement phases during the alignment between RE and V&V. Table 6 shows a mapping between RQ's and research methods.

Table 6 Mapping between RQ's and Research Methodology

Research Methodology	Research Questions
Systematic Literature Review	RQ1,RQ 1.1, RQ2, RQ3, RQ4, RQ4.1
Survey	RQ1, RQ2, RQ3, RQ4.1

4 RESULTS AND ANALYSIS OF SYSTEMATIC LITERATURE REVIEW

4 Results

20 relevant papers were identified during all snowballing iterations.

4.1.1 Start set

Start set was derived in two phases

- Phase 1: In this phase, from 3202 results 32 results were considered as tentative start set after performing inclusion and exclusion criteria along with going through abstracts/titles.
- Phase 2: Finally, from these 32 results 10 results were considered as a start set based on number of relevant citations and references. The selection of start set also carried out by going through the title, looking at the relevant study and then abstract of each candidate. Finally, full text of all these 10 results is read before considering for start set. Table 7 presents the selected start set papers with an identifier (S) for each paper.

ID	Citation of papers
S1	Barmi, Zeinab Alizadeh, Amir Hossein Ebrahimi, and Robert Feldt. "Alignment of requirements specification and testing: A systematic mapping study."Software Testing, Verification and Validation Workshops (ICSTW), 2011 IEEE Fourth International Conference on. IEEE, 2011.
S2	Kukkanen, Johanna, et al. "Applying a systematic approach to link requirements and testing: A case study." Software Engineering Conference, 2009. APSEC'09. Asia-Pacific. IEEE, 2009.
S3	Sabaliauskaite, Giedre, et al. "Challenges in aligning requirements engineering and verification in a large-scale industrial context." requirements engineering: foundation for software quality. Springer Berlin Heidelberg, 2010. 128-142.
S4	Post, Hendrik, et al. "Linking functional requirements and software verification."Requirements Engineering Conference, 2009. RE'09. 17th IEEE International. IEEE, 2009.
S5	Uusitalo, Eero J., et al. "Linking requirements and testing in practice."International Requirements Engineering, 2008. RE'08. 16th IEEE. IEEE, 2008.
S6	Graham, Dorothy. "Requirements and testing: Seven missing-link myths."Software, IEEE 19.5 (2002): 15-17.
S7	Larsson, Jacob, and Markus Borg. "Revisiting the challenges in aligning RE and V&V: Experiences from the public sector." Requirements Engineering and Testing (RET), 2014 IEEE 1st International Workshop on. IEEE, 2014.
S8	Wnuk, Krzysztof, Linus Ahlberg, and Johannes Persson. "On the delicate balance between RE and Testing: Experiences from a large

	company."Requirements Engineering and Testing (RET), 2014 IEEE 1st International Workshop on. IEEE, 2014.
S9	Bjarnason, Elizabeth, et al. "Challenges and practices in aligning requirements with verification and validation: a case study of six companies." Empirical Software Engineering 19.6 (2014): 1809-1855.
S10	Unterkalmsteiner, Michael, Robert Feldt, and Tony Gorschek. "A taxonomy for requirements engineering and software test alignment." ACM Transactions on Software Engineering and Methodology (TOSEM) 23.2 (2014): 16.

Table 7 Start set

4.1.2 First iteration

After identification of the start set, backward and forward snowballing were performed by going through the references and citations for each paper in the start set. Seven papers were selected in the first snowballing iteration. Figures for first iteration were shown in Appendix F.

4.1.2.1 Backward snowballing for first iteration

During the backward snowballing for start set papers, 280 references were evaluated. 56 were removed after considering the publication year, 22 were removed based on publication type, 153 were removed by screening the titles, 53 were removed by going through the abstract and full text, 18 were duplicates. Finally, four papers (S11, S14, S15, S16) were considered for the next iteration.

4.1.2.2 Forward snowballing for first iteration

During the forward snowballing for start set of papers, 237 citations were evaluated. In this, 101 citations were removed based on title and abstract, 29 were removed based on language, 38 duplicates were removed and 66 were removed by reading the full text and abstract. Finally, two papers (S13, S14) were considered for the next iteration.

Table 8 Results for first iteration

ID	Citation
S11	Metsä, Jani, Mika Katara, and Tommi Mikkonen. "Testing non-functional requirements with aspects: An industrial case study." Quality Software, 2007. QSIC'07. Seventh International Conference on. IEEE, 2007.
S12	Lobo, Lester O., and James D. Arthur. "Local and global analysis: Complementary activities for increasing the effectiveness of requirements verification and validation." Proceedings of the 43rd annual Southeast regional conference-Volume 2. ACM, 2005.

S13	Aichernig, Bernhard K., et al. "Integration of Requirements Engineering and Test-Case Generation via OSLC." Quality Software (QSIC), 2014 14th International Conference on. IEEE, 2014.
S14	Bjarnason, Elizabeth, et al. "An Industrial Case Study on Test Cases as Requirements." Agile Processes, in Software Engineering, and Extreme Programming. Springer International Publishing, 2015. 27-39.
S15	Ferguson, Robert W., and Giuseppe Lami. "An empirical study on the relationship between defective requirements and test failures." Software Engineering Workshop, 2006. SEW'06. 30th Annual IEEE/NASA. IEEE, 2006.
S16	Bjarnason, Elizabeth, et al. "Alignment practices affect distances in software development: a theory and a model." Proceedings of the 3rd SEMAT Workshop on General Theories of Software Engineering. ACM, 2014.

4.1.3 Second Iteration

In second iteration, two papers were selected after performing backward and forward snowballing for identified papers during first iteration. Figures for second iteration were shown in Appendix F.

4.1.3.1 Backward snowballing for second iteration

During backward snowballing, 124 references were evaluated. In this, 33 were removed based on the year of publication, 11 were duplicates, 54 were removed by reading the title, 16 were removed by reading full text. Therefore, in total 2 papers (S17, S18) are considered for the next iteration.

4.1.3.2 Forward snowballing for second iteration

During forward snowballing, 39 citations were evaluated. In this, 4 duplicates were removed, 9 were removed based on language, 23 were removed by going through title and 2 were removed by going through abstract and full text. Therefore, no papers were selected for the next iteration. Among first iteration of papers, two were not cited. Therefore, these 2 papers were not considered for forward snowballing.

Table 9 Results for second iteration

ID	Citation
S17	Melnik, Grigori, Frank Maurer, and Mike Chiasson. "Executable acceptance tests for communicating business requirements: customer perspective." (2006): 35-46.
S18	Bjarnason, Elizabeth. "Distances between requirements engineering and later software development activities: a systematic map." Requirements Engineering: Foundation for Software Quality. Springer Berlin Heidelberg, 2013. 292-307.

4.1.4 Third Iteration

In third iteration, two papers are selected after performing backward and forward snowballing for identified papers during second iteration. Figures for third iteration were shown in Appendix F.

4.1.4.1 Backward snowballing for third iteration

During backward snowballing, 69 references were evaluated. In this, 2 duplicates were found. 17 were removed based on the year of publication, 37 were removed by reading title, 13 paper was removed after reading full text and abstract. No papers were considered for the next iteration.

4.1.4.2 Forward snowballing for third iteration

During forward snowballing, 44 citations were evaluated. In this, 4 duplicates were found. 6 were removed based on the language, 26 were removed by going through title and 8 were removed after reading full text and abstract. Therefore, in total two papers (S19, S20) were selected for conducting backward and forward snowballing.

Table 10 Results for third iteration

ID	Citation
S19	Melnik, Grigori, Kris Read, and Frank Maurer. "Suitability of fit user acceptance tests for specifying functional requirements: Developer perspective." Extreme programming and agile methods-XP/Agile Universe 2004. Springer Berlin Heidelberg, 2004. 60-72.
S20	Ricca, Filippo, et al. "Talking tests: an empirical assessment of the role of fit acceptance tests in clarifying requirements." Ninth international workshop on Principles of software evolution: in conjunction with the 6th ESEC/FSE joint meeting. ACM, 2007.

4.1.5 Fourth iteration

In third iteration, two papers were selected after performing backward and forward snowballing for identified papers during third iteration.

4.1.5.1 Backward snowballing for fourth iteration

During backward snowballing, 20 references were evaluated. In this, 2 duplicates were found. 12 were removed based on the year of publication, 6 were removed after going through title and abstract and 2 were removed after reading full text. Therefore, no papers were considered for the next iteration.

4.1.5.2 Forward snowballing for fourth iteration

During forward snowballing, 43 citations of S19, S20 were evaluated. In this, 4 duplicates were found. 6 were removed based on the language, 26 were removed by going through title and 6 were removed after reading the full text and abstract. Therefore, no relevant papers are considered for the next iteration. After completion of fourth iteration there are no relevant paper found for conducting snowballing.

4.2 Distribution of studies related to alignment

After conducting the snowballing procedure and filtering the studies based on title, abstract, inclusion and exclusion criteria and full text reading, 20 primary studies were identified which were considered relevant to this study. Studies were considered from the year 2002 to 2015[8]. The year wise distribution of studies according to the year of publication is presented in Figure 7. Most of the studies (S [7], S [8], S [9], S [10], S [13], S [16]) were published in the year 2014. Most of these studies describes about the challenges during the alignment between RE and V&V (S [7], S [8], S [9], S [16]) and remaining two studies describe about the taxonomy for RE and software test alignment (S [10]), and integration of RE and test case generation (S [13]).

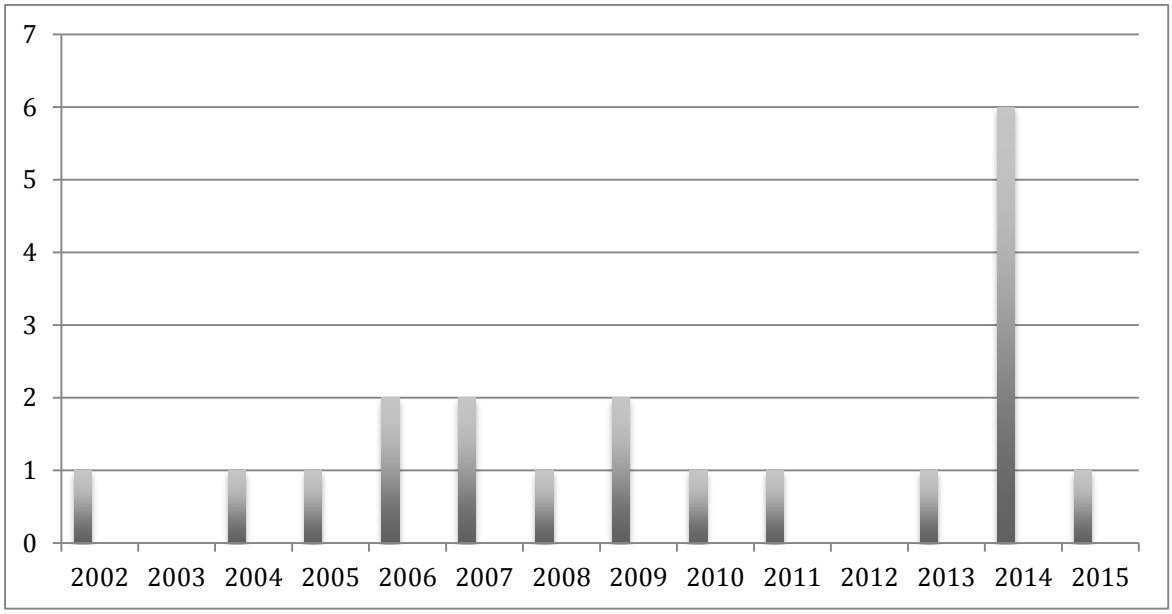


Figure 7 Distribution of studies over publication years

4.3 Categorization based on studies

Based on the suggestions given by Runeson et al.[53] and Wierlinga et al. [54], the results obtained after performing snowballing procedure were categorized into the two dimensions, namely methodology (Survey, case study, tool proposal and framework) and type of study (proposal, evaluative, validation and solution). The categorization of these two dimensions can be seen in the Figure 8.

Out of 20 studies, 12 studies (S3, S4, S8, S9, S10, S12, S13, S15, S16, S17, S18, S19) were considered as evolution research, two studies were proposing solution (S20, S2) and three studies proposed a frame work for aligning test cases with requirements (S7, S11, S14) and two studies were considered as secondary studies (S2, S15) and one study (S6) did not describe the research method. Among the identified studies, evolutions using case study research methodology were dominated and three studies were classified into case study-

solution category and two case studies in each of validation and proposal category. Evolutions using experimentation was found in four studies. Finally, framework-solution and framework-proposal received only 1 study each. No studies were found in survey, experimentation-proposal, solution and also in framework-validation, evolution. This shows that most of the considered studies were performed in industrial context and adds a value to the selected studies through snowballing procedure.

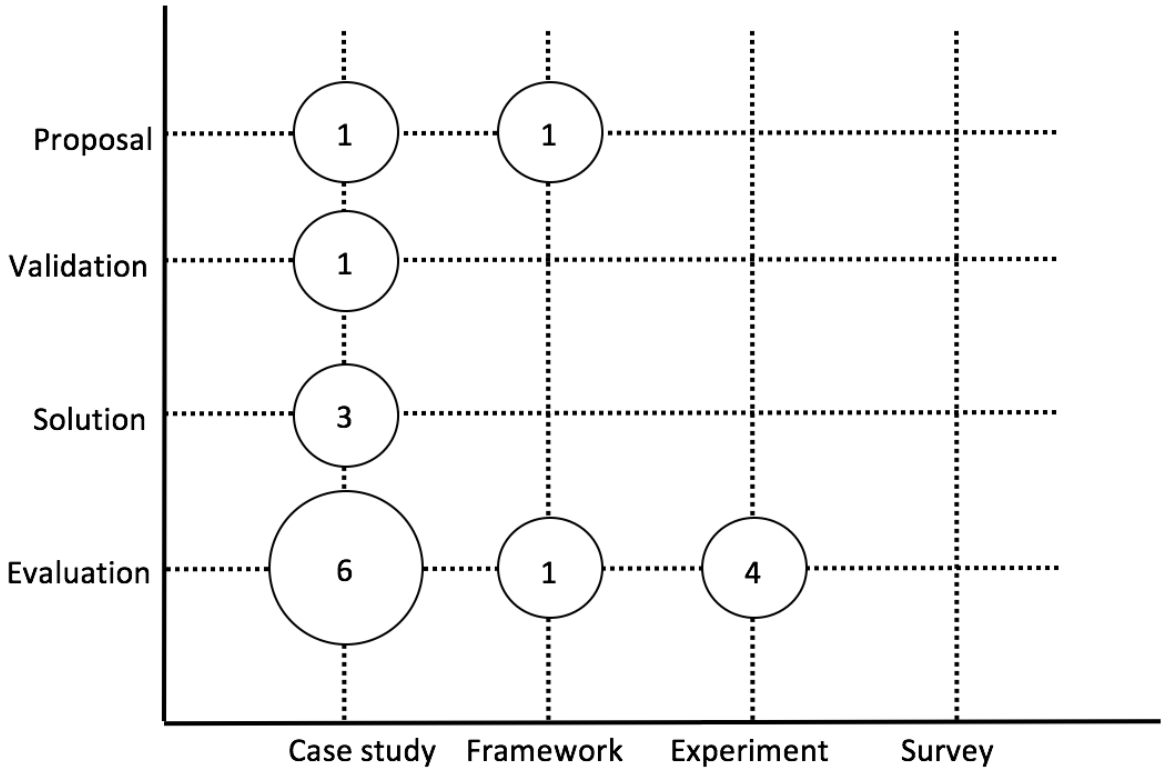


Figure 8 Classification of primary studies

4.4 Quality assessment based on rigor and relevance

Among the 20 identified studies, 8 studies (S2, S4, S7, S5, S3, S9, S16, S10) are classified as having highest rigor and relevance, see area A in Figure 9 and these are the most trustworthy results. Moreover, 5 studies (S8, S11, S12, S14, S15) in category B are classified as having high relevance but low rigor. On the other hand, category C contains 4 studies with low relevance and low rigor, see area C in Figure 9 and no studies were identified with high rigor and low relevance, see area B in Figure 9. The rigor and relevance scores for the identified studies were attached in appendix B. This in whole depicts that selected studies are relevant to this research. For secondary studies (S2, S15) quality assessment based on rigor and relevance is not considered. Most of the studies with higher rigor relevance describes about the RE practices, RE process factors, organizational factors and challenges during the alignment between RE and V&V, which were relevant to this research study.

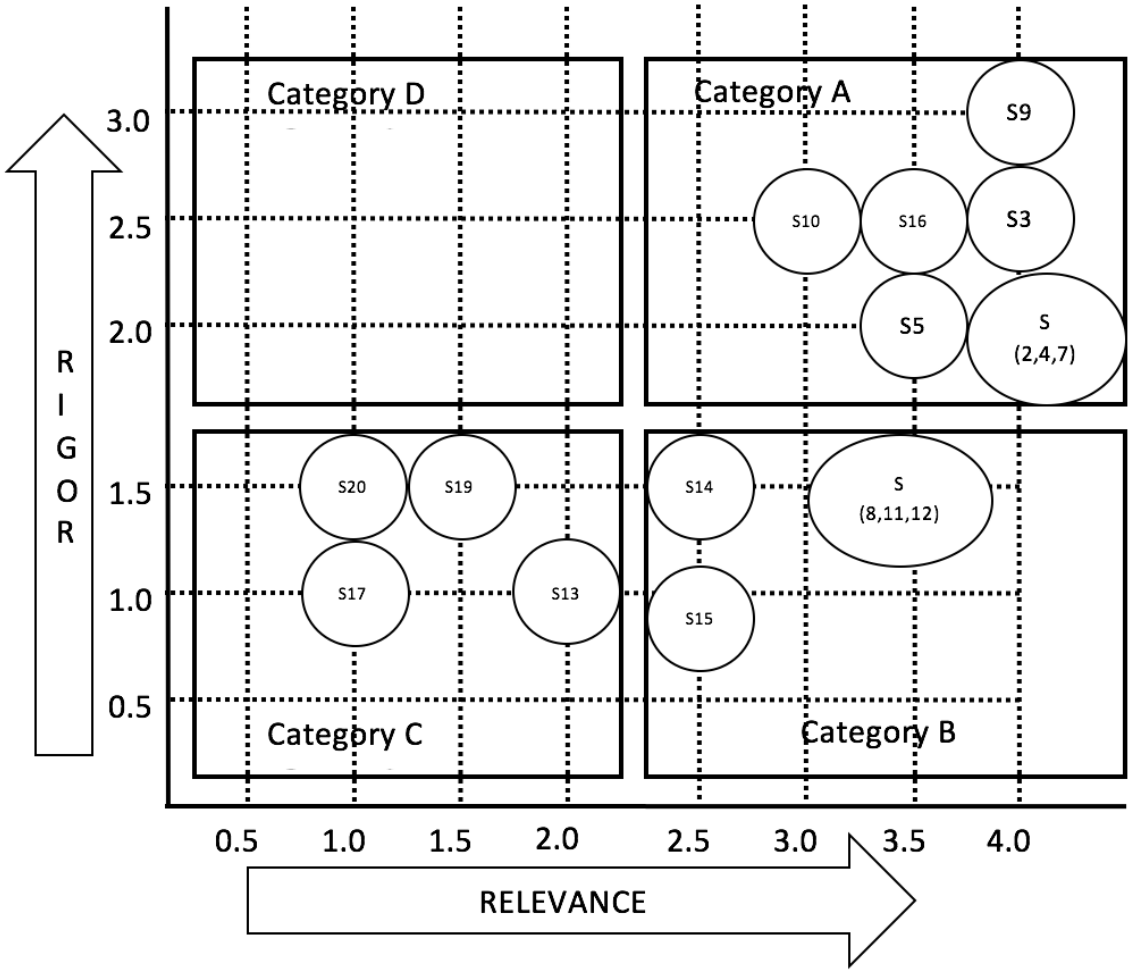


Figure 9 Categorization of studies based on rigor and relevance

4.5 Quality assessment criteria for secondary studies

Quality assessment for secondary studies should be performed in order to minimize the bias and maximize the internal and external validity of the study[55]. The quality criteria such as specification of methodology, specification of clear results etc. and scale of measurement (Yes, Partially, No) are presented in Table 11. The detailed quality assessment of secondary studies is presented in appendix C.

Table 11 Quality assessment checklist

No	Quality Criterion	Option		
		Yes	No	Partially
1.	Has research methodology clearly specified?			
2.	Clear specification of motivations and validations			

3.	Clear specification of results			
4.	Mentioning of validity threats			

The analysis of literature regarding RE practices, RE process factors, organizational factors and challenges from the identified studies is carried out in the following sections 4.6,4.7,4.8 and 4.9.

4.6 Analysis of literature regarding RE practices during the alignment

In this section the analysis of primary studies is carried out regarding the RE practices that are used while improving the RE and V&V alignment.

Six studies [S1] [S2] [S5] [S9] [S14] [S16] discuss different practices that are used during the alignment of RE and V&V. From the Figure 9 it can be observed that most of these studies ([S2] [S5] [S9] [S16]) have high rigor and relevance. Uusitalo et al.[10] (S[5]) Performed an interview study to identify practices that are used for strengthening the alignment between RE and testing. The study has primarily concentrated on identification of practices used for strengthening the link between RE and testing and has also identified the challenges, benefits during application of these practices, see Table 12. During this study some of the interviewee considered linking people and linking documents as the essential for alignment of RE and testing. This linking of people and documents also suggested in a case study conducted by Kukkanen et al. [9] (S[2]) in order to identify the set of good practices that helps the concurrent improvement of RE and testing processes. They also discuss the roles and their main responsibilities that are need to link requirements and testing. This case study results show that, it is important to perform linking in three levels 1) linking processes 2) linking of people and 3) applying good practices along with linking of people and documents.

Thereafter, Barmi et al. [8] (S[1]) has performed a systematic mapping study on alignment of requirements specification and testing. They identified the studies that discuss on linking the specification and testing of requirements. In this study they discussed the problems and set of good practices in aligning the requirements and testing. Similar practices are also discussed in a case study performed by Bjarnason et al.[17] (S[14]) to identify the scenarios for applying the alignment practices. These findings also include benefits and challenges in using test cases for validating, eliciting, tracing, verifying and managing requirements. Overall, this case study provide how the discussed practices meet the requirement roles at different stages.

Thereafter, in a multi case study of six companies Bjarnason et al. [2] (S[9]) has identified 27 different alignment practices, grouped into 10 categories. They also discuss challenges faced while application of practices such as cross role requirements reviews, product manager review types, early verification start, document level traces, test cases as requirements, traceability responsibility role, independent testing etc., details of identified practices can be seen in Table 12. These challenges are namely V&V quality, full test coverage, verifying quality requirements etc. are mapped with the 27 alignment practices. These findings help practitioners and researchers for recognizing challenges faced and practices applied to address these challenges during the alignment between RE and V&V.

In another study Bjarnason et al.[18] (S[16])discuss alignment practices that affect the distances in software development. They primarily focused on the practices that affect the

distances in software development. And some of the studies S [14] have not mentioned about impact of the identified practices during the alignment.
The practices considered while applying alignment between RE and V&V are [S1] [S2] [S5] [S9] [S14] [S16] presented in Table 12.

Table 12 Identified RE practices from literature after clustering

Paper ID	Discussed practices
S5	• Early tester participation (S5_1) • Testers participation in requirement review(S5_2) (S9_3) • Test traceability to requirements(S5_3) • Linking testers with requirements owners(S5_4) • Requirement suggestion by testers(S5_5)
S2	• Communication(S2_1) • Metrics and visibility(S2_2) • Roles & responsibilities(S2_3) • Review teams(S2_4) • Review requirements(S2_5) • Change control tools(S2_6)
S9	• Development involved in detailing requirements(S9_2) (S16_19) • Customer communication at all requirement levels and phases(S9_1) (S16_18) • Subsystem expert involved in requirements definition(S9_5) • Documentation of requirement decision rationales(S9_6) • Test cases reviewed against requirements(S9_7) • Acceptance test cases defined by customer(S9_8) • Product manager review prototypes(S9_9) • Management base launch decision on test report(S9_10) • User/customer testing(S9_11) (S16_23) • Early verification start(S9_12) • Independent testing(S9_13) (S16_24) • Testers re-use customer feed back from previous projects(S9_14) (S16_25) • Training off-shore testers(S9_15) • Process for requirement change involving VV(S9_16) (S16_26) • Product-line requirements practices(S9_17) (S16_27) • Process enforcement(S9_18) • Document level traces(S9_19) (S16_28) • Requirements-test case traces(S9_20) (S16_29) • Test cases as requirements(S9_21) (S16_30) • Same abstraction level for requirements and test specs(S9_22) • Traceability responsibility role (S9_23) • Tool support for requirement and testing(S9_24) (S16_31) • Tool support for requirements-test cases tracing(S9_32) • Alignment metrics(S9_26) • Job rotation(S9_27)

S16	• Use of a customer proxy role(S16_1) • Feature requirements documentation(S16_2) • Product manager physically present to developers & testers(S16_3) • Informal communication within organization(S16_4) • Product manager involved in development project. (S16_5) • Same process for QR's(S16_6) • Structure requirements artefacts that accord to type(S16_7) • Collaborative definition of quality requirements(S16_8) • Early test involvement in development projects(S16_9) • Feature based test plan(S16_10) • Separate testing team for quality requirements(S16_11) • Test impact analysis(S16_12) • Close cooperation between test and development unit and roles(S16_13) • Conceptual tracing(S16_14) • Traces between people/roles(S16_15) • Incremental development(S16_16) • Small-scale development(S16_17)
S1	• Involving testers during project plan (S1_1) • Requirements review (S1_2)
S14	• A De facto practice (S14_1) • TCR practice through behavior driven development tool (S14_2)

These are the identified practices that are identified through the primary studies. As mentioned previously these aspects cover the practices that are used during the alignment of requirements and testing. These practices are needed for an organization in to order to achieve the RE and V&V alignment. This constitutes to the identification of the RE practices that are used during the alignment of RE and V&V S[9], S[16], S[2], S[5]. The obtained literature is also analyzed in order to identify RE practices used in specific to requirement phases. Before clustering all the practices (Table 12), the resulted practices through literature can be seen in Appendix E. Identified RE practices through literature are mentioned and discussed below.

Requirement engineering practices

RE practices are at the core of aligning the RE and V&V[2]. These practices include involving development near roles, informal communication within organization and customer communication in the requirement process.

- **Customer communication at all levels and in all phases of development (S9_1 (S16_18):** Communication can be made in the mode of customer-supplier co-location, customer based interaction used for demonstration on executable software or agreed acceptance criteria between customer and supplier [2].For smaller companies with bespoke requirements interaction is directly with a physical customer. Whereas, in larger companies customer proxy is used instead of real customer for the interaction [2]. In each development team a person should take responsibility for the feature scope. However, that person should be available to communicate throughout the development and the validation of particular feature [2]. Therefore, this practice should be carried out all requirements phases to ensure the communication with customers.

- **Involving developers and testers in detailing requirements (S9_2) S16_19):**
  This practice is considered as a deliberate strategy for conveying the main goal of the product to the engineers rather than detailing requirements. Here development organization will take the responsibility of detailing the specification. This may be considered as a risky practice if there is a weak awareness of the market perspectives or customers [2]. This practice also consist of involving testers at the early stages of the entire project[10]. This benefits in improving the testers domain and system knowledge [2].
- **Cross role requirement reviews (S9_3)(S16_20):**
  This practice is applied to ensure that requirements are understood and testable. The practical procedures for the review of requirements are namely early review of requirements by testers, reviewing the requirements while creating test cases. Furthermore, this practice enhances both quality of requirements and communication resulting in strengthening the alignment of the testing effort. Therefore, this practice helps in identifying problems with the test specification at early stages [2].
- **Defining a requirements review responsible (S9_4) :**
  Kukkanen et al. [9] discovered the role of assurance manager overlaps with test and requirement manager roles. They stress the importance of an additional responsible role for requirement reviews. Hence, defining a requirement review responsible was mentioned as a practice [2]. This ensures that requirement reviews are performed. This role is decided during the requirement analysis phase.
- **Involving domain experts in requirement definition (S9_5):**
  This practice is applied to achieve better co-ordination between system capabilities and requirements. This leads to defining more realistic requirements [2]. By applying this practice, domain experts will know if they understand the requirement correctly or not [2]. This practice also considered for supporting the alignment by improving the quality of requirements, which were the basis for software testing.
- **Documentation of requirement decision rationales (S9_6):**
  This practice increases the synchronization between different project phases by supporting transfer of soft communication between different roles[2]. After completion of development, this information will support testers in evaluating customer defect reports and in identifying required improvements. However, this information should be easily connected and available to the test cases and requirements for the use of testers in later stage of development [2].

The above mentioned RE practices are discussed in literature that influences the alignment between RE and V&V. These are the practices that positively affect the alignment of RE and V&V [2][9][10][14].Whereas, Bjarnason et al. has discussed about the additional practices that were identified through the analysis performed for constructing the GAP model[18]. Following are the identified RE practices used for RE and Testing (RET) alignment by Bjarnason et al [18].

- Use of customer proxy role (S16_1).
- Feature requirement documentation (S16_2).
- Product manager physically present to developers & testers (S16_3).
- Informal communication with in organization (S16_4).
- Same processes for quality requirements(S16_6).
- Structure requirement artefacts accord to type (S16_7).
- Collaborative definition of quality requirements (Quality requirements, e.g. performance, usability etc.). (S16_8).

Bjarnason et al. [18] mentioned about the additional identified practices. However, they have not discussed their impact on the study of alignment. They primarily focused on how these practices are showing impact on distances i.e. geographical distance, organizational distance, cognitive distance. In specific, they discussed how two RE practices (i.e. product manager physically present to developers & testers, collaborative definition of quality requirements) impact the distances.
It is important to notice that some practices such as requirements test case traces, same abstraction levels for requirement specifications are not considered as RE practices. This is due to fact that Bjarnason et al.[2], have simplified the view of RE and V&V alignment, by considering traceability activities to be different from RE practices. Therefore, in this thesis the author has considered only RE practices without traceability practices as suggested by Bjarnason et al. [2].

Table 13 presents the list of all identified RE practices used during the alignment and their usage at different requirement phases.

Table 13 Applying RE practices at different requirement phases

ID	Description	Requirement phases			
		Elicitation	Analysis	Specification	Validation
P1	Customer communication at all levels and in all phases of development (S9_1) (S16_18)	X	X	X	X
P2	Involving developers and testers in detailing requirements (S9_2) (S16_19)			X	
P3	Cross role requirement reviews (S9_3) (S16_20)		X		
P4	Requirements review responsibilities defined (S9_4)		X		
P5	Subsystem expert involved in requirements definition (S9_5)	X			
P6	Documentation of requirements decision rationales (S9_6)			X	
P7	Use of a customer proxy role (S16_1)	X			
P8	Feature requirements documentation (S16_2)			X	
P9	Informal communication within organization (S16_4)	X	X	X	X

P10	Same process for quality requirements (S16_6)	X	X	X	X
P11	Structure requirement artefacts accord to type (S16_7)			X	
P12	Collaborative definition of quality requirements. (S16_18)	X			

Many of these RE practices namely customer communication at all requirement levels & phases, informal communication with in organization, same process for quality requirements, product manager physically present to developers & testers should carried out through all the requirement phases. Development involved in detailing requirements and documentation of requirement decision rationale practices are considered in both requirement analysis and specification phases. It is done more during the requirement specification phase. Feature requirements documentation is another practice that is involved in the specification and analysis phase. This practice is considered to ensure that requirements are actually analyzed and defined on feature level instead of all possible levels. The use of a customer proxy role and collaborative definition of quality requirements practices are considered during requirement elicitation and analysis phases, however more intensively in the requirement specification phase.

4.7 Analysis of literature regarding RE process factors during the alignment

Primary studies were also analyzed in order to identify the influence of various RE process factors during the alignment. Identification of the impact of RE process factors while implementing practices is one of the areas in this research.

Many of the authors have tried to provide influence of RE process factors during the alignment. Sabaliauskaite et al. [6] mentioned the influence of RE process factors i.e. source of requirements, however without deeper analysis. The emphasis was made on identifying the challenges rather than influence of process factors on the alignment. Similarly, Bjarnason et al. [17] discussed the process factors, while performing a case study to find the benefits and challenges in using test cases for elicitation, validating, verifying, tracing and managing requirements. During this study they have discussed the consideration of process factors i.e. source of requirements, requirements in typical project. In a similar study to this, Kukkanen et al.[9] stressed to know the importance of factors which may shorten the development time and improve the quality. In another study[2], Bjarnason et al. also considered several process factors while applying different alignment practices. They mainly focused on discussing the challenges faced while applying the identified set of alignment practices along with some process factors. Similarly, the studies [18][1] have reported influence of the RE process factors while applying the alignment practices.

The RE process factors that are discussed while applying the alignment practices are:

- Source of requirements
- Distance between development of requirements and testing
- Testability of requirements

Influence of each identified RE process factors on alignment is as follows:

- **Distance between development of requirements and testing**: Sometimes, development units and testing units will not give enough attention and consideration to the requirements [6]. During development developers do not always review requirements and this might be due to lack of involvement of testers and developers in requirement reviews[6].
- **Testability of requirements:** Testability of the requirements is not considered by the requirement engineers. This leads in turning out requirements to be non-testable [6]. Therefore, this might show negative impact on the alignment.
- **Source of requirements:** Source of requirements can be market driven and bespoke. However, some organizations with more number of requirements will use both bespoke and market driven development as a source of requirements[2], [17]. Organizations with bespoke requirements will interact directly with a physical customer whereas, customer proxy will be used in organizations with market driven development [2].

4.8 Analysis of literature regarding influence of organizational factors during the alignment

In this section, the identified studies were analyzed in order to identify the influence of organizational factors during the alignment of RE and V&V. Identification of the impact of organizational factors is one of the research areas in this research.
Many of the authors tried to provide influence of organizational factors during the alignment. Sabaliauskaite et al. [6] discussed the influence of organizational factors i.e. organizational structure, gaps in communication across different organizational units, however without details. Similarly, Bjarnason et al.[18] discussed influence of organizational factors during a study to present an initial version of a theory based on the GAP model. During this study they have discussed the organizational factors that influence the alignment i.e. size of an organization, domain and range of an organization. In another case study [2] Bjarnason et.al also considered different organizational factors for applying alignment practices. They focused on discussing the challenges faced while applying the identified set of alignment practices along with organizational factors.
The following are the identified organizational factors while applying the alignment practices:

- Organizational structure
- Gaps in communication across different organizational units
- Distance in time between the development of requirements and test artifacts
- Size of an organization
- Domain/system type

Influence of each identified organizational factor is as follows:

- **Size of an organization:** Bjarnason et al. [2] emphasized that the alignment vary between the companies depending upon their size. Organizations with smaller project groups can handle alignment through a combination of informal and formal meetings. Whereas, organizations with larger scale projects need more efficient tools and processes to ensure the co-ordination of communication between different hierarchies and phases in an organization[2]. The alignment supported by tools was well in medium sized projects, but for the larger companies there was an occurrence of frequent alignment challenges[2]. Therefore, size of the organization plays a crucial role in applying alignment practices[18].

- **Gaps in communication across different organizational units:** Sabaliauskaite et al. [6] discusses gaps in communication across different organizational units affect the alignment. In larger companies gaps in communication and co-ordination among different organizational units frequently arises, especially at the high level[6]. Furthermore, different persons regarding the gaps in communication will give different answers. Therefore, it is difficult to find the root cause of each challenge. Therefore, this could affect the alignment. Especially, the alignment gets affected at a high abstraction level of the processes and requirements[6].
- **Distance in time between the development of requirement and test artifacts:** Sabaliauskaite et al.[6] discussed that distance in time between the development of requirements and test artifacts can create alignment problems. They said that requirements are being approved without having any test cases associated with them. This can end up in having non-testable requirements[6], which affects the alignment.
- **Organizational structure:** In [6][2][17], it was mentioned that organizational structure affect the alignment. If the organization is very large and many organizational units are involved and every organizational unit may not follow the same documentation process and standard for the documentation. This may raise the issues in the organization regarding communication. Hence, this may negatively affect the alignment.
- **Domain/system type:** Bjarnason et al.[18] mentioned that safety-critical development systems are externally motivated for applying alignment practices. Whereas in non-safety critical systems the motivation is purely internal[18]. Due to low awareness of the cost vs. benefits of RE and V&V alignment, internal motivation is considered as weak in some organizations.

4.9 Analysis of literature regarding the challenges that are addressed by RE practices during the alignment

To identify the challenges that are faced while implementing alignment practices the analysis was done two fold: first for challenges that are faced during alignment and then for the challenges or problems that are addressed by alignment practices.

Many authors tried to provide the challenges that are lack of alignment practices. Uusitalo et al. [10] conducted an empirical study to present a set of good practices that are applied to create a strong link between RE and testing. During the discussion of alignment practices they mentioned about the challenges occurred namely availability of testers during early stage of the project, suggestions given by testers are often in the wrong scope, maintenance of traceability between requirements and testing, adding new requirements etc. During this study most interviewees reported deficiencies in the requirement process to be a large hindrance to linking RE and V&V together. Kukkanen et al.[9] Conducted a case study to identify a set of new practices that helped to perform the alignment between RE and V&V. They discussed the frequency of some challenges when applying good practices namely communication, metrics and visibility, roles and responsibilities, review teams, reviews, change control and tools. In addition, they have mentioned that keeping test cases up-to date during requirement change process is a major challenge.

Similarly, Sabaliauskaite et al.[6] conducted an empirical study to identify key challenges in aligning requirements and verification processes. It was observed that practitioners use findings of these studies as a basis for investigating alignment. They mentioned issues related to organization and processes, people, tools, requirement process, testing process, change management, traceability and management. In this study, it was observed that communication

and co-ordination between different units with in a company is a major challenge along with traceability and software tools[14]. Bjarnason et al. [2] conducted a multi-unit case study to identify current industry challenges and practices in aligning RE and V&V. In this study, an overview of relationships between the alignment challenges and practices is provided. This mapping is considered in addressing most pressing alignment challenges. Thereafter, in a case study Larsson et al.[56] discuss identified alignment challenges and their occurrence related to development of large information system for public sector. In this case study, they divided the challenges into two categories: the most occurred such as aligning goals with in an organization, co-operating successfully etc. and least occurred such as full test coverage, defining a good verification process, tracing between requirements and test cases.
The challenges that are identified in aligning requirements with verification and validation are:
Ch1: Different standards of the documentation.
Ch2: Frequent process changes
Ch3: Distance in time between development of different test artefacts and requirements.
Ch4: Lack of appropriate tools influences the alignment.
Ch5: Aligning goals and perspectives within organization.
Ch6: Co-operating successfully.
Ch7: Non-testable requirements.
Ch8: Defining clear and verifiable requirements
Ch9: Defining complete requirements
Ch10: Keeping requirements documents updated.
Ch11: Full test coverage
Ch12: Defining a good verification process
Ch13: Lack of knowledge to testers on dealing with high level requirements
Ch14: Verifying quality requirements
Ch15: Maintaining alignment between requirements and testing when requirements change
Ch16: Co-ordination requirements at different abstraction levels
Ch17: Tracing between requirements and test cases
Ch18: Tracing between requirements abstraction levels
Ch19: Costs associated with the involvement of several organizational units
Ch20: Lack of verification at early stages of the requirements
Ch21: Difficult to find appropriate metrics for alignment.
Ch22: Time and resource availability
Ch23: Managing a large document space
Ch24: Outsourcing of components
Ch25: Defining requirements at abstraction levels well matched to test cases

Following are the identified challenges that are addressed by RE practices from the literature:

T1: ***Aligning goals and perspectives within organization (Ch. 5)***
The synchronization between requirements and testing is affected by unaligned goals and causes confusion between organizational units of the joint development projects[2], [6].

T2: ***Cooperating successfully (Ch. 6)***
Due to lack of co-operation between requirements related people, developers and testers will affect alignment negatively[2]. Therefore, testers should have a good communication with requirements related and development related roles, to increase the alignment. Lack of awareness of the responsibilities and tasks can also negatively affect the alignment [2], [6].

T3: ***Requirements specification quality***

Defining clear and verifiable requirements **(Ch. 8)** is considered as a major challenge in enabling good alignment between requirements and V&V [2]. Non-verifiable requirements will cause problems to developers and testers during the development of customer-correct software. Defining clear requirements will help for successful alignment [17]. Complete requirements **(Ch. 9)** will ensure the full test coverage by verifying full functionality and quality aspects of the requirements. Keeping requirements documentation updated **(Ch. 10)** is consider as another challenge for aligning requirements and V&V [2].

T4: ***V&V quality***

To full fill the final requirements and expectations of the customer full test coverage **(Ch. 11)** is considered as an important aspect [6]. As mentioned earlier, non-verifiable requirements cause main difficulties to achieve full test coverage of requirements and lack of traceability will affect in whether achieving full test coverage or not [2], [6], [57]. Late requirements changes **(Ch. 12)** are also considered as other factor that affects the full test coverage to requirements. Verifying quality requirements **(Ch. 14)** and test cases are considered as another challenge in aligning with requirements [2].

T5: ***Requirements abstraction levels***

Defining requirements at different abstraction stages will ensures test cases in line with the requirements along with a good coverage of test cases [2]. Coordinating requirements at different abstraction levels **(Ch. 16**) is considered as another challenge because it is hard to co-ordinate breaking down detailed requirements into detailed requirements at component level [2].

T6: ***Outsourcing or offshoring of components or*** **testing (Ch. 24)**

Tracing between artefacts and implementing agreed detailed requirement to test are the challenges created by outsourcing or offshoring of components [2]. *Timing* plays crucial role in tracing component requirement specification during the outsourcing at early in the development of the project. *Specification* of the test cases related to testing type is important, when test is outsourced [2].

4.9.1 RE practices that address the identified challenges

This section describes about the relationships between the alignment challenges and RE practices identified from the literature. This mapping benefits practitioners in choosing RE practices to consider in addressing the alignment challenges. The connections between RE practices and challenges are derived through the analysis of the literature gathered from the snowballing procedure. From the mappings (Table 14) it can clearly observe that there are many-to-many relationships between identified RE practices and challenges. From the Table 14 it can also be observed that practices from P7-P12 did not address any challenges, no literature has been found regarding these practices. Therefore, these practices are posed in survey to find which challenges they address during the alignment between RE and V&V.

T1: ***Aligning goals and perspectives within organization (Ch. 5):***

'Aligning goals and perspectives within organization' challenge is addressed by identified RE practices such as P1, P2, P3, P5 and P6 to increase the synchronization and communication between different roles and units with in organization[2], [9]. However, this synchronization and communication can be achieved through involvement of costumers and development near roles in the requirements process [2]. Therefore, practices such as customer

communication at all levels and phases, development involved in detailing requirements, cross-role requirement reviews, sub-system expert involved in requirement definition and documentation of requirement decision rationale were used to address this challenge (T1).

T2: ***Cooperating successfully (Ch. 6)***
'Cooperating successfully' challenge is addressed by identified RE practices such as P2, P3, P5 and P6 to achieve close cooperation among roles and organizational borders [2]. However, this close co-operation can be achieved through involvement of cross-functional teams and reviews. Therefore, practices such as development involved in detailing requirements, cross-role requirement reviews, sub-system expert involved in requirement definition and documentation of requirement decision rationale were used to address this challenge (T2).

T3: ***Requirements specification quality***
'Requirements specification quality' challenge is achieved by defining clear and verifiable requirements, keeping requirements document updated and also defining complete requirements [2]. Therefore, challenge of achieving requirements specification quality is addressed by identified RE practices namely practices customer communication at all levels and phases, development involved in detailing requirements, cross-role requirement reviews, sub-system expert involved in requirement definition and requirements review responsibilities defined were used to address this challenge (T3) [2].

T4: ***V&V quality***
As mentioned earlier achieving verification and validation quality depends upon aspects namely full test coverage, late requirement changes and verifying quality requirements. Therefore, challenge of achieving good verification and validation quality is addressed by identified RE practices such as customer communication at all levels and phases, development involved in detailing requirements, cross-role requirement reviews, sub-system expert involved in requirement definition and requirements review responsibilities defined were used to address this challenge (T4) [2].

T5: ***Requirements abstraction levels***
Defining requirements at different abstraction stages will ensures test cases in line with the requirements along with a good coverage of test cases [2]. Therefore, challenge of managing requirement abstraction levels is addressed by identified RE practices such as involvement of the customer throughout all requirement phases and documentation of requirement rationale.

T6: ***Outsourcing or offshoring of components or*** **testing (Ch. 24)**
As mentioned previously, outsourcing challenge is related to timing and specification. These two are project management issues and the requirements are communicated with the external team (outsourced team), who develop or test these requirements. However, to achieve the good communication practices related to communication are considered along with the practices for improved cooperation[2]. Therefore, practices such as customer communication at all levels and phases, development involved in detailing requirements, cross-role requirement reviews, sub-system expert involved in requirement definition and requirements review responsibilities defined were used to address this challenge (T6) [2].

	T1	T2	T3	T4	T5	T6
P1: Customer communication at all requirement levels & phases	X		X	X	X	X
P2: Development involved in detailing requirements	X	X	X	X		X
P3: cross-role requirement reviews	X	X	X	X		X
P4: Requirements review responsibilities defined			X	X		X
P5: Sub system expert involved in requirements definition	X	X	X	X		X
P6: Documentation of requirement decision rationale	X	X			X	
P7: use of customer proxy role						
P8: feature requirement documentation						
P9: informal communication with in organization						
P10: software processes for quality requirements						
P11: structure requirement artefacts						
P12: Collaborative definition of quality requirements						

Table 14 Mapping of identified RE practices to challenges

4.10 Discussion and conclusion of SLR

In total 20 studies were identified after conducting the snowballing procedure. Based on the research questions, this research is based on three factors. Firstly, identification of RE process factors and organizational factors impact during the alignment between RE and V&V. Based on this aspect, the primary studies were analyzed and impact of RE process factors and organizational factors that are considered during the alignment between RE and V&V was identified. Wnuk et al.[S8] mentioned that the influence of additional factors to achieve alignment between RE and V&V and shift of balance due to influence of these factors can be explored. Therefore, additional factors limited to RE process factors and organizational factors are considered during the alignment between RE and V&V were identified from the studies. After the analysis of the literature it can be observed that much focus is not carried out on the influence of factors and further exploration is required to know the impact of factors during the alignment between RE and V&V.

Secondly, this study is also focused on identification of the challenges that were faced while aligning RE and V&V. This secondary aspect of this research was done two fold, primarily to identify the generic challenges that are faced during the alignment between

RE and V&V and then to identify specific challenges that are addressed by RE practices. Based on the data extraction strategy the identified studies were analyzed to identify the generic challenges that were faced during the alignment between RE and V&V. Studies such as [S3], mentioned some challenges faced without mentioning the practices that address those specific challenges and some studies such as [S7] provided challenges faced in public sector during the alignment between RE and V&V. Similarly, the identified studies were analyzed and the generic challenges that are faced during the alignment between RE and V&V were identified.

The challenges that are addressed by practices during the alignment are also analyzed. As mentioned previously, relatively less focus was given in the literature regarding the identification of challenges that are addressed by individual practices during the alignment between RE and V&V. Some of the studies such as [S2] [S5] have focused on specific practices and provided the literature regarding the impact of these practices on alignment. Therefore, studies were analyzed and challenges that are addressed by practices were also identified.

Finally, the research is focused on the identification of specific challenges that are addressed by RE practices during the alignment between RE and V&V. There was very less focus in the literature regarding the RE practices that are used in organizations to address the challenges. Studies such as [S9] and [S16] have provided some RE practices that are used to address the challenges that faced while alignment between RE and V&V. As the studies reported were less, the available studies were analyzed and the challenges that are addressed by RE practices are identified and mapped. The list of identified challenges that are addressed by different RE practices are listed in Table 14. Unaddressed challenges (in Table 14) by different RE practices will be addressed through the industrial survey.

5 RESUTS AND STATISTICAL ANALYSIS OF SURVEY

5.1 Analysis of general information about survey participants

The survey was prepared using online web application survio. After posting the survey in different groups, mailing different persons, positing in different social networking platforms such as Facebook, LinkedIn the author has received 54 responses in which, 48 complete responses were considered. This implies that rate of completion of the survey is 88%, which is sufficient to consider the results of the survey valuable [58]. This helps in knowing that quality of questionnaire is high and it was easy to understandable by the practitioners.

Participants in the survey were asked to provide their geographical location, results of the respondents is analyzed and provided in the Figure 11. The participants came from various parts of the globe such as India, USA, UK, Sweden, Denmark, Singapore, Germany, Australia etc. have submitted their responses. From Figure 11, it can be observed that most of the participants are from India (30%) [14 respondents] and other countries have lesser representatives- Sweden (21%) [10 respondents], USA (13%) [6 respondents], UK (9%) etc.

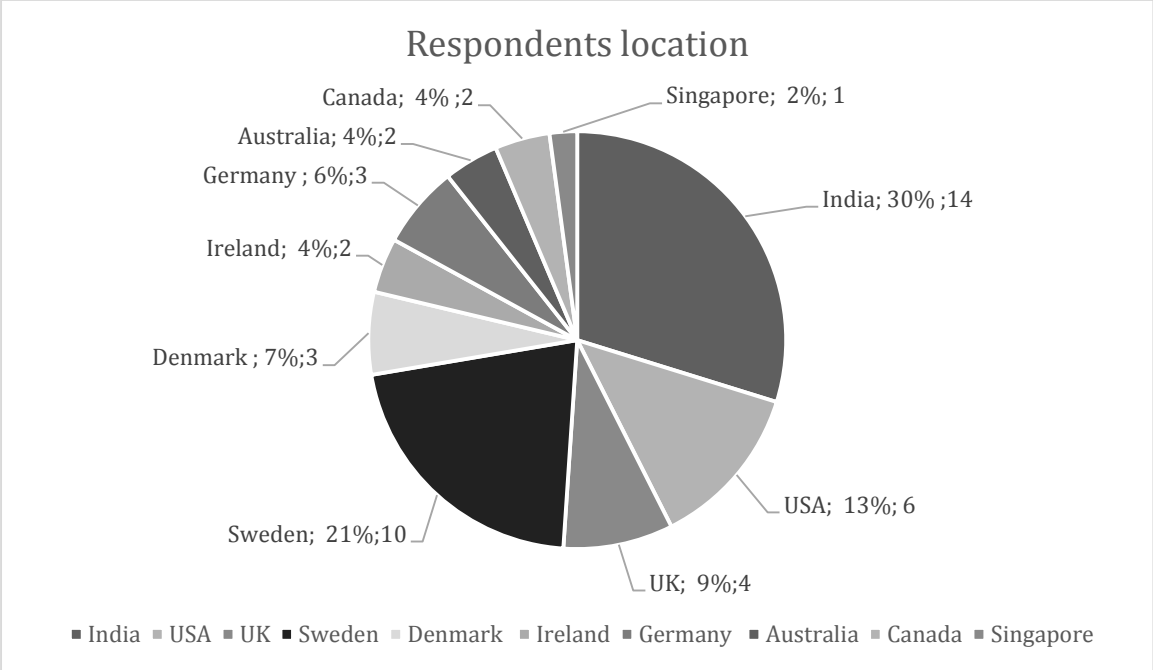


Figure 10 Distribution of respondents based on geographical locations in percentages

Author has asked respondents about the size of organization (in terms of people) in which they are working. Table 15 provides the results of this demographic aspect.

Table 15 Categorization of Organization size based on people

Number of people	Organization size
Below 250	Very small
251-1000	Small
1001-5000	Medium
5001-10000	Large
More than 10000	Very large

From the responses, it can be observed that nearly half of the respondents were working in large scale organizations (45%), followed by medium scale organizations (25%) with quarter of respondents and Very large scale organizations (23%). Very less number of people are working in small scale (4%) and very small scale (4%) organizations.

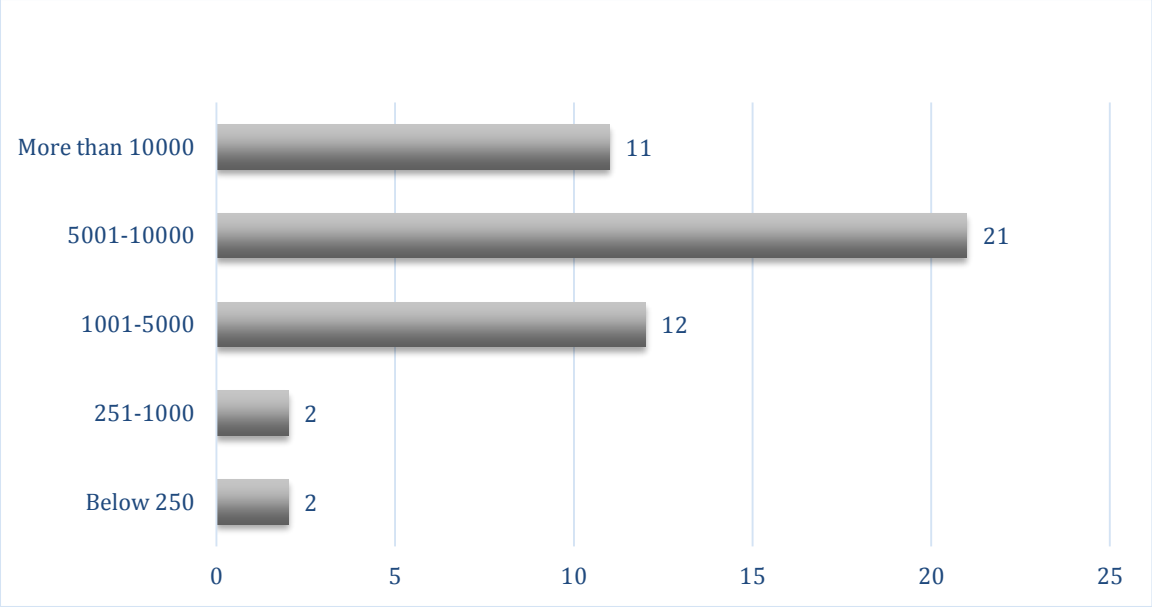


Figure 11 Size of the organization of respondents in numbers

As this research is focused on RE practices and RE process factors alignment between RE and V&V, knowledge about and the experience working with requirement is very essential. This makes the experience in requirements engineering as a required factor for this research. Therefore, the author has asked for participant's experience (in years) in requirement engineering. The majority of respondents (33%, 15 respondents) reported 5-7 years of experience within related to requirements while 26% (12 respondents) of the respondents are having 7-10 years of experience followed by 6% of respondents having 10-15 years of experience. To summarize, 66% of the respondents have more than 5 years of experience within related to requirements, which helps to validate that the results can be of high quality. The experience of the respondents within related to requirements is depicted in Figure 12.

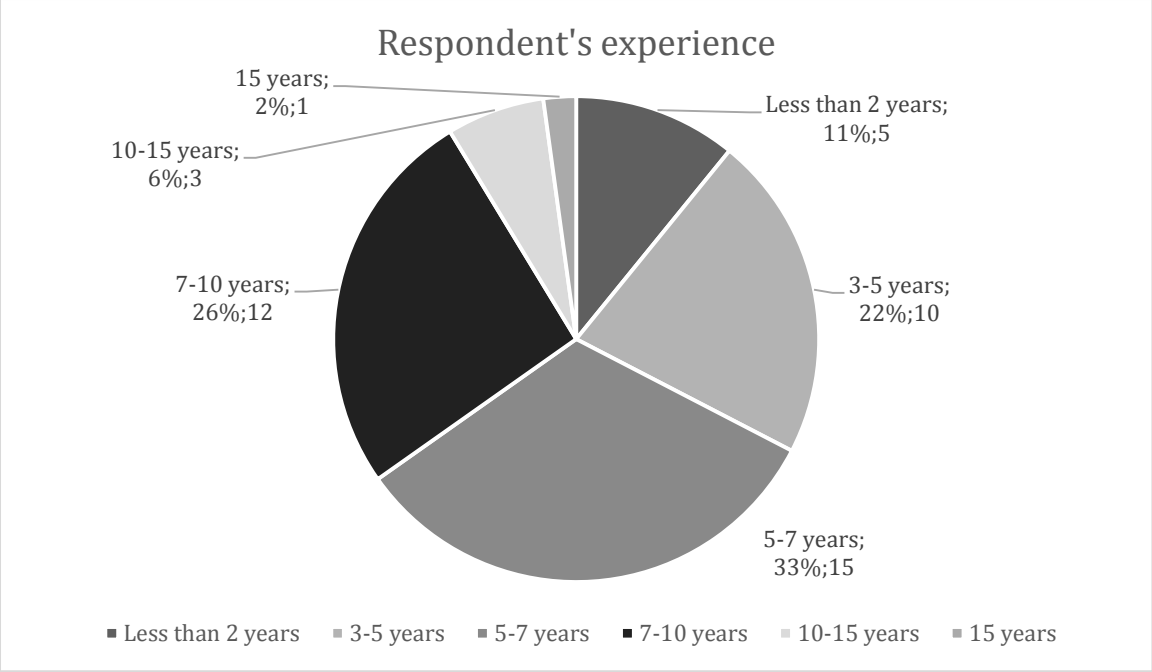


Figure 12 Respondents experience within related to requirements

Regarding respondent's roles, 26% (27 respondents) of the respondents were requirement analysts with, followed by developers/testers (15%, 16 respondents), Business analysts, quality analysts and requirement engineers (12%, 12 respondents). Requirement Managers (11%) are also included in the respondents. Under other option the respondents mentioned test manager and test lead. In total respondents related to requirements are in high number (49%), which shows respondents of the survey are familiar with the topic. The roles are depicted in Figure 13.

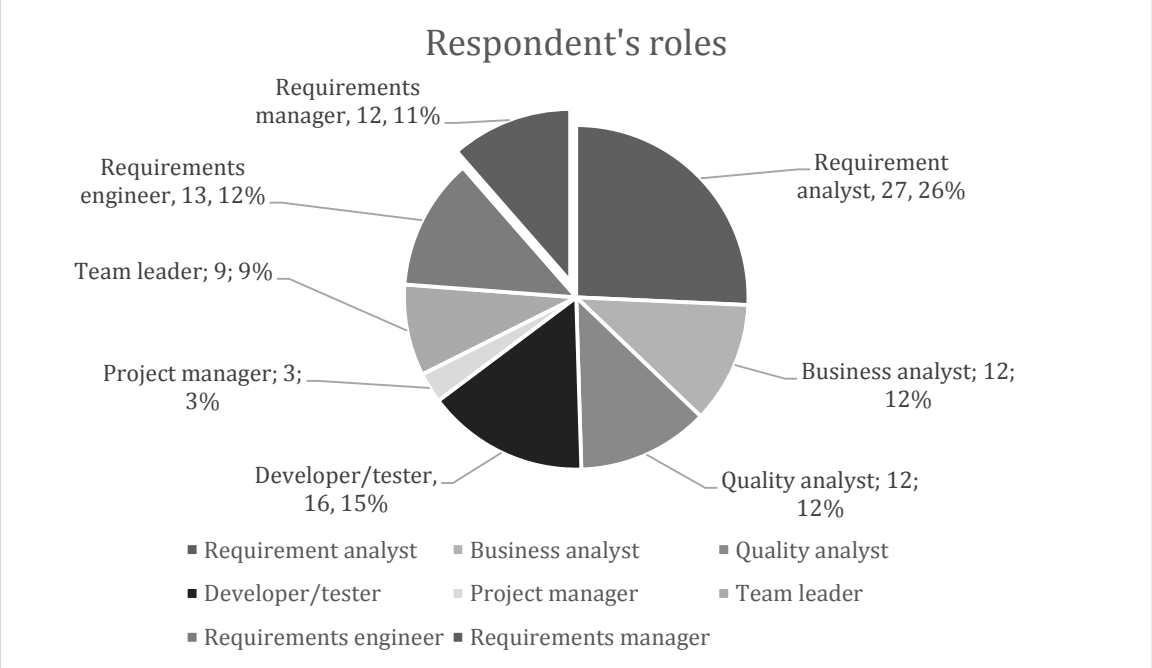


Figure 13 Respondent's roles in percentages

5.2 Influence of the identified REs process factors, organizational factors during the alignment between RE and V&V

In order to identify the impact of identified RE process factors, organizational factors during the alignment between RE and V&V identified in the literature were listed and the corresponding questions (see questions 6 and 8 in Appendix A) were asked in the questionnaire.

Here respondents were asked to select the impact (Positive, Neutral, Negative) of the RE process factors and organizational factors from the list of provided RE process factors and organizational factors identified through the literature. It is important to notice that results obtained for this question are computed based on the number of respondents received for each factor. Here respondent is allowed to select only one option, so the analysis is done on the basis of number of respondents and not over number of responses.

Thereafter, responses were analyzed and respondent's perspective is provided in the form of heat maps, see Table 16, 17. Heat maps shows the number of responses obtained for each RE process factor and organizational factor with respect to impact as specified by participant of the survey. In these heat maps, the strongest value of impact is shown with solid color and weak impact is shown in light color.

Table 16 Heat map for impact of identified RE process factors during the alignment between RE and V&V

	Positive	Neutral	Negative	Don't know
Source of requirements	5	25	17	1
Distance between development of requirements and testing	3	18	26	1
Testability of requirements	5	8	35	0

From the heat map (Table 15) the respondents selected 'Testability of requirements' as the most important factor with 35 responses (72.9%) that negatively influences the alignment between RE and V&V. The 'Distance between development of requirements and testing' (54.3%). is also considered as the factor, which negatively influences the alignment between RE and V&V along with the factor source of requirements which does not show(neutral) impact on the alignment with 25(52.3%) respondents. These results confirm the previous experiences (see section 4.7) of the practitioners derived from the systematic literature review.

Furthermore, results of the questionnaire were used for finding the relationships between identified RE process factors (variable 1) on one side and size of the organization, experience within related to requirements and role in the organization (variable 2 each) on the other side.

This existence of relationship was measured using chi-square test significance (see Section 3.8.2).

From the figure 12, it can be observed that most number of respondents 45% (21) are working in large scale organizations, followed by medium scale organizations 25% (12) and very large scale organizations (23%). The *null hypothesis (H0)* assumes that there is no relationship between RE process factors and size of the organization. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables.

After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is rejected i.e. there is no significant relationship between these two variables (Chi-square value= 30.217^{a}, df=15, p=0.011<0.05). But, there are more than 20% of cells with expected count less than 5 (83.3%), this violates the chi-square test condition. Therefore, it is considered as there is no relationship between identified RE process factors and size of the organization.

Furthermore, from the responses it was observed that the majority of the respondents were requirement analysts (26%), followed by testers/developers, Business analysts, Quality analysts and Requirement engineers (12%). Requirement Managers (11%) are also included in the respondents. Under other option respondents mentioned test manager and test lead. But, the responses provided under others option were merged with requirements manager to reduce the number of cells that received less than 5.

Chi-square significant test is used to find a relationship between RE process factors and role of the respondents. The *null hypothesis (H0)* assumes that there is no relationship between RE process factors and role of the respondents. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables. After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is accepted i.e. there is no significant relationship between these two variables (Chi-square value= 6.985^{a}, df=4, p=0.137>0.05). But, there are more than 20% of cells with expected count less than 5 (60.2%), this violates the chi-square test condition.

Furthermore, the relationship is calculated with the remaining aspect experience within related to requirements. The majority of the respondents 33% are having 5-7 years of experience within related to requirements. Also 20% of the respondents are having 7-10 years of experience followed by 6% of respondents having 10-15 years of experience. It is important to notice that less than 1-year experience respondents were merged with 1-2 years of experience and more than 15 years of experience respondents were merged with 10-15 years of experience to reduce the number of cells count less than 5. It is known that experience practitioners related requirements plays a crucial role during the alignment. Therefore, the author searches for a relationship between RE process factors and experience of respondents within related to requirements.

Chi-square significant test was used to find a relationship between RE process factors and role of the respondents. The *null hypothesis (H0)* assumes that there is no relationship between RE process factors and experience of respondents. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables. After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is rejected i.e. there is no significant relationship between these two variables (Chi-square value= 32.100^{a}, df=15, p=0.006<0.05). Therefore, *alternative hypothesis (H1)* is accepted i.e. there is significant relationship between RE process factors and experience of the respondents. But, there are more than 20% cells with expected count less than 5 (23.5%), which can be neglected and value of Cramer's V is 0.672 shows strong relationship between variables (see Table 17). Therefore, the results shown in the Table 15 are reliable and cross tabulated result is presented in Table 18.

Table 17 Chi-square test results for identified RE process factors and experience of respondent

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	32.100[a]	15	.006
Likelihood Ratio	18.079	15	.259
N of Valid Cases	48		

a. 9 cells (23.5%) have expected count less than 5. The minimum expected count is .04.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.818	.006
	Cramer's V	.672	.006
N of Valid Cases		48	

Table 18 Contingency table between RE process factors and work experience of respondents

RE process factors / Work Experience	Source of requirements	Distance between development of requirements and testing	Testability of requirements
Less than 2 years	6.3%	4.0%	14.3%
3-5 years	18.8%	24.0%	20.1%
5-7 years	18.8%	28.0%	28.6%
7-10 years	37.5%	28.0%	22.9%
More than 10 years	18.3%	16.0%	14.3%

From observing results in Table 18, it clearly depicts that most of the respondents are having handful of experience (>5 years) related to requirements, which constitutes the results obtained from the survey are reliable. To, conclude there is a statistical significance relationship between RE process factors and work experience of respondents, whereas there is no relationship between RE process factors and size of an organization, respondent roles.

Similarly, from the heat map (Table 19) it can be observed that the respondents selected 'Distance in between development of test artefacts and requirements' as the most important factor with 29 respondents (60.4%) that considered it negatively influencing the alignment between RE and V&V. The structure of an organization with 27 respondents (56.3%) followed by size of an organization with 25 respondents (51.6%) were also considered as factors that affect the alignment negatively. Gaps in communication across different organizational units and domain/system type are also considered as factors that negatively

influence the alignment between RE and V&V with relatively less number of respondents 24 (50%) and 23 (49.2%). After analyzing the responses, it can be observed that these results are in concordance with the results mentioned in section 4.8.

Table 19 Heat maps for impact of identified organizational factors during the alignment between RE and V&V

	Positive	Neutral	Negative	Don't know
Organizational structure	3	16	27	2
Gaps in communication across different organizational units	3	19	24	2
Distance in between development of requirements and test artefacts	2	16	29	1
Size of an organization	3	18	25	2
Domain/System type	3	17	23	5

Furthermore, results of the questionnaire were used for finding the relationships between identified organizational factors (variable 1) on one side and size of the organization, experience within related to requirements and role in the organization (variable 2 each) on the other side. This existence of relationship is measured using chi-square test significance (see Section 3.8.2). Therefore, from the responses it was observed that majority of the respondents were requirement analysts (26%), followed by testers/developers, Business analysts, Quality analysts and Requirement engineers (12%). Requirement Manager (11%) are also included in the respondents. Under other option respondents mentioned test manager and test lead. But, the responses provided under others option were merged with requirements manager to reduce the number of cells that received less than 5.

Chi-square significant test was used to find a relationship between organizational factors and experience of respondents. The *null hypothesis (H0)* assumes that there is no relationship between organizational factors and experience of respondents. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables. After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is accepted i.e. there is no significant relationship between these two variables (Chi-square value= 6.927^{a}, df=3, p=0.074>0.05). But, there are more than 20% of cells with expected count less than 5 (50.2%), this violates the chi-square test condition.

Furthermore, the relationship was calculated with the remaining aspect experience within related to requirements. 33% of the respondents have 5-7 years of experience related to requirements. Also 20% of the respondents are having 7-10 years of experience followed by 6% of respondents having 10-15 years of experience. It is important to notice that less than 1-year experienced respondents were merged with 1-2 years of experienced to reduce the

number of cells count less than 5. It is known that experience practitioners related requirements plays a crucial role during the alignment. Therefore, the author searches for a relationship between organizational factors and experience of respondents within related to requirements.

Chi-square significant test was used to find a relationship between organizational factors and experience of the respondents. The *null hypothesis (H0)* assumes that there is no relationship between organizational and experience of respondents. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables. After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is rejected i.e. there is no significant relationship between these two variables (Chi-square value= 20.729^{a}, df=15, p=0.146>0.05). But, there are more than 20% cells with expected count less than 5 (83.5%), this violates chi-square test condition. Therefore, *alternative hypothesis (H1)* is not accepted.

Similarly, from the figure 12, it can be observed that most number of respondents 45% (21) are working in large scale organizations, followed by medium scale organizations 25% (12) and very large scale organizations (23%). The *null hypothesis (H0)* assumes that there is no relationship between organizational factors and size of the organization. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables.

After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is rejected i.e. there is no significant relationship between these two variables (Chi-square value= 23.393^{a}, df=15, p=0.007<0.05). Therefore, it is considered as there is relationship between identified organization factors and size of the organization, which is *alternative hypothesis (H1)*. Chi-square test results and Cramer's V values are outlined in Table 20. Therefore, the cross tabulation is performed between organizational factors and size of the organization (see Table 21).

Table 20 chi square test for organizational factors and size of the organization

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	23.393[a]	15	.007
Likelihood Ratio	19.143	15	.207
N of Valid Cases	48		

a. 6 cells (19.3%) have expected count less than 5. The minimum expected count is .04.

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.698	.076
	Cramer's V	.403	.076
N of Valid Cases		48	

Table 21 Contingency table for Organizational factors and size of an organization

Org. factors / Size of Org.	Organizational structure	Gaps in communication across different organizational units	Distance between development of requirements and test artefacts	Size of an organization	Domain/System type
Less than 250	3.7%	8.2%	3.6%	4.0%	0%
251-1000	3.7%	4.2%	0%	4.0%	0%
1001-5000	27.4%	44.2%	25.7%	38.0%	28.7%
5001-10000	44.4%	15.8%	60.7%	32.0%	47.8%
> 10000	20.7%	27.5%	10.0%	22.0%	23.5%
Total	100%	100%	100%	100%	100%

From the results it can be observed that organizational factors are having more impact during alignment on very large scale organizations and large scale organizations when compared to the small scale and very small scale industries, which is depicted in the literature results (see section 4.7). To conclude, there is a statistical significance relationship between the identified organizational factors and size of the organization.

5.3 Level of occurrence of the identified challenges during the alignment between RE and V&V

Respondents were asked to rate the level of occurrence of identified challenges i.e. high, medium, low (see question 11 in Appendix A). The rating is on a scale from 3 to 1 where 3 is 'high' and 1 is 'low'. For this question the challenges which were discussed as the most important by [2], [56] are considered. It is important to notice that results obtained for this question are computed based on the number of respondents received for each factor. The analysis is done performed for the number of respondents and not over number of responses.

Thereafter, the responses were analyzed and respondent's perspective is provided in the form of heat maps, see Table 21. Heat maps shows the number of responses obtained for each challenge. In this heat map (Table 21), the highly occurred challenges are shown with solid color and low occurred were shown in light color.

It can be observed from the Table 22 that challenges namely managing large document space, verifying quality requirements, time and resource availability, maintain alignments when requirements change, co-operating successfully, tracing between abstraction levels are the highly faced challenges. While outsourcing of components, defining requirements at abstraction level well matched to test cases, full test coverage, defining clear and verifiable requirements, aligning requirements and perspectives with organizations are considered as less occurred challenges.

Table 22 Heat maps for level of occurrence of identified challenges during alignment between RE and V&V

	High	Medium	Low	Don't know
Aligning requirements and perspectives with the organization	23	24	0	1
Co-operating successfully	25	21	1	1
Defining clear and verifiable requirements	20	25	2	1
Keeping requirements documents updated	26	20	1	1
Full test coverage	20	24	3	1
Defining a good verification	21	23	3	1
veryfying quality requirements	30	15	2	1
Maintainig alignment when requirements change	26	20	1	1
Defining requirements at abstraction level well matched to test cases	10	27	2	9
Co-ordinating requirements at different abstraction levels	19	16	11	2
Tracing between requirements abstraction levels	24	22	0	2
Time and resource availability	28	17	2	1
Managing a large document space	34	10	2	2
Outsourcing of components	8	32	4	4

Furthermore, results of the questionnaire were used for finding the relationships between identified challenges (variable 1) on one side and size of the organization, experience within related to requirements and role in the organization (variable 2 each) on the other side. This existence of relationship was measured using chi-square test significance (see Section 3.8.2). Therefore, from the responses it was observed that majority of the respondents were requirement analysts (26%), followed by testers/developers, Business analysts, Quality analysts and Requirement engineers (12%). Requirement Manager (11%) are also included in the respondents. Under other option respondents mentioned test manager and test lead. But,

the responses provided under others option were merged with requirements manager to reduce the number of cells that received less than 5.

Chi-square significant test was used to find a relationship between identified challenges and experience of respondents. The *null hypothesis (H0)* assumes that there is no relationship between identified challenges and experience of respondents. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables. After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is rejected i.e. there is no significant relationship between these two variables (Chi-square value= 5.240^{a}, df=2, p=0.073>0.05). But, there are more than 20% of cells with expected count less than 5 (33.3%), this violates the chi-square test condition. Therefore, the *alternative hypothesis (H1)* cannot be accepted.

Furthermore, the relationship was calculated with the remaining aspect experience within related to requirements. The majority of the respondents 33% are having 5-7 years of experience within related to requirements. Also 20% of the respondents are having 7-10 years of experience followed by 6% of respondents having 10-15 years of experience. It is important to notice that less than 1-year experience respondents were merged with 1-2 years of experience to reduce the number of cells count less than 5.

Chi-square significant test was used to find a relationship between challenges and experience of the respondents. The *null hypothesis (H0)* assumes that there is no relationship between organizational and experience of respondents. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables. After calculating the chi-square test, it can be observed that *null hypothesis (H0)* is accepted i.e. there is no significant relationship between these two variables (Chi-square value= 26.729^{a}, df=10, p=0.003<0.05). Therefore, *alternative hypothesis (H0)* is accepted i.e. there is no significant relationship between challenges and experience of the respondents. But, there are more than 20% cells with expected count less than 5 (83.5%), this violates chi-square test condition.

Similarly, from the figure 12, it can be observed that most number of respondents 45% (21) are working in large scale organizations, followed by medium scale organizations 25% (12) and very large scale organizations (23%). The *null hypothesis (H0)* assumes that there is no relationship between organizational factors and size of the organization. Whereas, *alternative hypothesis (H1)* predicts a significant relationship between these two variables.

After calculating the chi-square test, it can be observed that *alternative hypothesis (H0)* is accepted i.e. there is significant relationship between these two variables (Chi-square value= 27.478^{a}, df=10, p=0.002<0.05). Therefore, it is considered as there is no relationship between identified challenges and size of the organization. Therefore, descriptive statistics was used with the Friedman test to find the standard deviation and mean of each challenge (non-parametric test), see Table 23[59].

Table 23 Descriptive statistics for identified challenges during the alignment between RE and V&V

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	Percentiles 50th (Median)	Percentiles 75th
[Aligning requirements and perspectives with in organizations]	48	1.56	.616	1	4	1.00	2.00	2.00

[Co-operating successfully]	48	1.54	.651	1	4	1.00	1.00	2.00
[Defining clear and verifiable requirements]	48	1.67	.663	1	4	1.00	2.00	2.00
[Keeping requirements documents updated]	48	1.52	.652	1	4	1.00	1.00	2.00
[Full test coverage]	48	1.69	.689	1	4	1.00	2.00	2.00
[Defining a good verification process]	48	1.67	.694	1	4	1.00	2.00	2.00
[Verifying quality requirements]	48	1.46	.683	1	4	1.00	1.00	2.00
[Maintaining alignments when requirements change]	48	1.52	.652	1	4	1.00	1.00	2.00
[Defining requirements at abstraction level well matched to test cases]	48	2.21	.988	1	4	2.00	2.00	2.00
[coordinating requirements at different abstraction levels]	48	1.92	.895	1	4	1.00	2.00	3.00
[Tracing between requirements abstraction levels]	48	1.58	.710	1	4	1.00	1.50	2.00
[Time and resource availability]	48	1.50	.684	1	4	1.00	1.00	2.00
[Managing a large document space]	48	1.42	.767	1	4	1.00	1.00	2.00
[Outsourcing of components]	48	2.08	.767	1	4	2.00	2.00	2.00

It is important to notice that the Friedman test was used to test the variance between each identified challenge and to generalize overall difference between the challenges. When there is no significant relationship (chi-square test) is identified between the two independent variables (e.g. identified challenges and work experience), non parametric test namely

Friedman test is used to find the standard deviation (variance) and the significance in accordance with every value can be shown with the use of mean rank. Therefore, mean rank (see Table 24) and variance (see Table 23) were calculated for the identified challenges.

Table 24 Mean rank for each identified challenge

Ranks

	Mean Rank
[Aligning requirements and perspectives with in organizations]	7.07
[Co-operating successfully]	6.93
[Defining clear and verifiable requirements]	7.76
[Keeping requirements documents updated]	6.84
[Full test coverage]	7.76
[Defining a good verification process]	7.67
[Verifying quality requirements]	6.24
[Maintaining alignments when requirements change]	6.83
[Defining requirements at abstraction level well matched to test cases]	9.61
[Coordinating requirements at different abstraction levels]	8.67
[Tracing between requirements abstraction levels]	7.14
[Time and resource availability]	6.61
[Managing a large document space]	5.89
[Outsourcing of components]	9.98

As can be observed from the statistical analysis, outsourcing of components has obtained a mean rank of 9.98, defining requirements at abstraction level well matched to test cases 9.61, coordinating requirements at different abstraction levels 8.67, defining a good verification process 7.67, full test coverage 7.76 and so on. Furthermore, these mean ranks were used to know the most occurred or important challenges during the alignment between RE and V&V.

5.4 RE practices that are applied at different requirement phases during the alignment between RE and V&V

Question 10 in the questionnaire covers the RE practices application at different requirement phases during the alignment between RE and V&V was asked. The respondents were allowed to choose more than one requirement phase i.e. elicitation, analysis, specification, validation (see question 10 in Appendix A) for each identified RE practice through literature.
The results obtained for this question were computed based on the number of responses received for each practice, as multiple selections were possible. The responses are depicted in the form of heat maps, see Table 25. Heat maps shows the number of responses obtained for application of each identified RE practice at the different requirement phases.
From the responses it can be observed that RE practices namely customer communication at all requirement levels & phases, informal communication with in organization, same process for quality requirements, product manager physically present to developers & testers should carried out through all the requirement phases i.e. analysis, elicitation, specification, validation. This depicts that the frequent usage of RE practices will tends to improve the alignment between RE and V&V, as discussed in literature.
Development involved in detailing requirements and documentation of requirement decision rationale practices are considered in both requirement analysis and specification phases. Feature requirements documentation is another practice that is involved in the specification and analysis phase. The use of a customer proxy role and collaborative definition of quality requirements practices are considered during requirement elicitation and analysis phases, however more intensively in the requirement specification phase.
It is important to notice that some of the RE practices such as structure requirement artefacts accord to type and feature requirement documentation is carried out in both analysis and specification phases. However, they are more implied at specification phase. This can be observed from number of respondents for each RE practice at each phase. Therefore, the author has considered the options which have more than 70% of responses. Thus, validation of results of literature is carried out on the basis of responses (see Table 25).

Table 25 Heat map for application of identified RE practices at different requirement phases

	Elicitaion	Analysis	Specification	Validation
Customer communication at all requirement levels and phases	42	44	42	43
Development involved in detailing requirements	11	23	42	12
Cross role requirement reviews	5	46	19	11
Requirement reviews responsibilities defined	6	43	6	9
Subsytem expert involved in requirement definition	39	16	6	10
Documentation of different requirement eciosn rationales	2	18	42	7
Use of customer proxy role	40	14	3	4
Feature requirements documentation	2	16	43	5
Informal communication within organization	39	43	41	41
Same process for quality requirements	40	44	39	39
Structure requirements artefacts accord to type	3	22	44	3
collaborative definition of qulaity requirements	36	25	8	3

The survey participants can select more than one option for this question, which means answers were not gathered on Likert scale basis. Therefore, chi square significance test is not performed for finding the relations between variables [50]. Therefore, the author has decided to do manual analysis for identification of variation in results between the less experienced (<5 years of experience) versus high experienced respondents (>5 years of experience). Manual analysis was carried out by exporting the survey results into the data excel sheets. Here candidates with experience less than 5 years are considered as "X" and candidates with experience more than 5 years are considered as "Y". Thereafter, for each RE practices analysis was carried out to know variance by comparing the total number of less experienced respondents (Category A) versus more experienced responses (Category B). This helps in validating the obtained responses with the factor of respondent's experience.

Table 26 Variance in responses within related to experience for identification of applied RE practices at different requirement phases

	Requirement phase							
	Elicitation		Analysis		Specification		Validation	
Experience	Category:A	Category:B	Category:A	Category:B	Category:A	Category:B	Category:A	Category:B
Customer communication at all requirement levels and phases.	13	29	14	30	13	29	14	29
Development involved in detailing requirements	1	10	8	15	12	30	2	10
Cross role requirements reviews	2	3	15	31	6	13	0	11
Requirements review responsibilities defined	3	3	14	29	3	3	0	9
Subsystem expert involved in requirements definition	11	28	4	12	3	3	0	10
Documentation of requirements decision rationales	0	2	5	13	14	28	1	6
Use of a customer proxy role	12	28	3	11	1	2	0	4
Feature requirements documentation	1	1	4	10	13	30	1	4
Informal communication within organization	11	28	14	29	12	29	12	29
Same process for quality requirements	12	28	13	31	12	27	12	27
Structure requirement artefacts accord to type	1	2	6	16	14	30	0	3
Collaborative definition of quality requirements	8	28	9	16	4	4	0	3

By comparing Table 25 and Table 26, it can be observed that many of the respondents were having more experience (Category B), this indicates that the responses collected from the survey are reliable and also considered for the purpose of validation of results. From the Table 26 it is observed that the category B responses are more in concordance with the results obtained in the literature, see Table 12.

5.5 Validation of identified RE practices addressing the challenges

In the questionnaire, a question about the RE practices addressing the alignment challenges was asked. The respondents were allowed to choose more than one challenge (see question 13 in Appendix A) for each identified RE practice through literature. This question helps in validating the results that were gathered during the literature study, see Table 27. From Table 27 we can see that results for RE practices namely feature requirement documentation, informal communication within organization, were not covered in the literature. Therefore, this question helps in identifying the challenges that were unaddressed by RE practices.

Table 27 Heat maps for identified RE practices addressing the challenges during the alignment between RE and V&V

	Aligning goals and perspectives within organization	Co-operating sucessfully	Requirements specification quality	V&V quality	Requirements abstraction levels	Outsourcing & offshoring of components
Customer communication at all requirement levels and phases	45	17	40	37	39	40
Development involved in detailing requirements	36	35	42	39	11	34
Cross role requirement reviews	38	42	44	40	7	35
Requirement reviews responsibilities defined	13	16	40	40	14	40
Subsytem expert involved in requirement definition	39	40	43	40	13	37
Documentation of different requirement decision rationales	39	40	15	9	36	7
Feature requirements documentation	3	11	45	43	13	12
Informal communication within organization	35	41	7	13	4	21
Software process for quality requirements	8	22	42	40	3	14
Structure requirements artefacts accord to type	7	41	27	28	23	2
collaborative definition of qulaity requirements	24	42	38	17	2	8

It is important to notice that the results obtained for this question are analyzed based on the number of responses received for each practice. Here the respondents were allowed to choose more than one challenge, therefore the analysis is done on the basis of number of responses and not over number of respondents. Thereafter, responses were analyzed and respondent's perspective is provided in the form of a heat map, see Table 27. Heat maps shows the number of responses obtained for addressing challenge of each identified RE practice.

The statistical analysis was carried out to know the variance in responses in terms of experience, organizations, role of respondents. However, chi-square test is not possible to

know the variances and significance because of providing more than one option to select for this question in the questionnaire. Therefore, the author has decided to do manual analysis for identification of variation in results from the obtained responses of the survey. This variance is calculated between the less experienced (<5 years of experience) versus high experienced respondents (>5 years of experience), requirement practitioners versus others and large organizations versus small organizations.

Firstly, to know the variance in responses the author considered less experienced respondents (<5 years of experience) as category A and more experienced respondents (>5 years of experience) as category B, then the analysis was carried out, see Table 28. Manual analysis was carried out by exporting the survey results into the data excel sheets. Here candidates with experience less than 5 years are considered as "X" and candidates with experience more than 5 years are considered as "Y". Thereafter, for each RE practices analysis was carried out to know variance by comparing the total number of less experienced respondents (Category A) versus more experienced responses (Category B).

Table 28 Variance in responses within related to experience for RE practices addressing the challenges

	Aligning goals and perspectives within organization		Co-operating successfully		Requirement specification quality		V&V quality		Outsourcing of components and testing		Requirements abstraction levels	
Experience	A	B	A	B	A	B	A	B	A	B	A	B
Customer communication at all requirement phases	15	30	3	14	14	26	13	24	13	27	13	26
Development involved in detailing requirements	12	24	13	22	14	28	14	25	9	25	8	3
Cross-role requirement review	14	24	14	28	10	34	13	27	10	25	5	2
Requirements review responsibility defined	1	12	3	13	11	29	13	27	12	28	8	6
Sub system expert involved in requirement definition	13	26	11	29	14	29	13	27	11	26	9	4
Documentation of requirement definition rationale	13	26	12	28	2	13	1	8	0	7	11	25
Feature requirement documentation	2	1	0	11	14	31	13	30	1	11	4	7
Informal communication within organization	9	26	11	30	3	4	1	12	0	21	2	2
Software process for quality requirements	4	4	1	21	13	29	13	27	2	12	2	1
Structure requirement artefacts	4	3	12	29	9	18	11	17	0	2	8	15
Collaborative definition of quality requirements	3	21	14	28	13	25	9	8	4	4	0	2

Here, from Table 27 and Table 28 it can be observed half of the survey respondents are having more experience (Category B). Let us consider the RE practice "customer communication at all levels and phases" addressing the challenge "aligning goals and perspectives within the organization", from Table 28 it is observed that in total 45 responses are obtained. Table 28 clearly depicts that in these 45 respondents 15 are less experienced (Category A) and 30 are more experienced (Category B). For structure requirement artifacts and co-operating successfully, 41 responses are obtained among which more experienced respondents are twice than the respondents with less experience and this variance can be easily observed in many of the RE practices, see Table 28. Therefore, this Table 28 helped for knowing the results are reliable and can be used for validation of results.

Similarly, to know the variance in responses the author considered small-medium organizations as category A and large-very large organizations as category B, then the analysis was carried out, see Table 29. Manual analysis was carried out by exporting the survey results into the data excel sheets. Here small and medium organizations are considered as "X" and large and very large organizations are considered as "Y". Thereafter, for each RE practices analysis was carried out to know variance by comparing the small-medium (Category A) versus large-very large organization (Category B).

Table 29 Variance in responses within related to size of organization for RE practices addressing the challenges

	Aligning goals and perspectives within organization		Co-operating successfully		Requirement specification quality		V&V quality		Outsourcing of components and testing		Requirements abstraction levels	
Organization	A	B	A	B	A	B	A	B	A	B	A	B
Customer communication at all requirement phases	14	31	5	13	13	27	11	26	10	30	10	29
Development involved in detailing requirements	11	25	12	23	11	31	11	28	9	25	8	3
Cross-role requirement review	9	29	11	31	14	30	11	29	7	28	10	4
Requirements review responsibility defined	3	10	5	11	12	28	10	30	10	30	9	5
Sub system expert involved in requirement definition	9	30	9	31	13	30	9	31	9	28	9	4
Documentation of requirement definition rationale	9	30	9	31	4	11	3	6	1	6	6	30
Feature requirement documentation	3	2	1	10	13	32	12	31	3	9	2	11
Informal communication within organization	10	25	10	31	5	4	3	10	2	19	3	1
Software process for quality requirements	2	6	7	15	12	30	12	28	7	7	3	0
Structure requirement artefacts	2	5	10	31	8	19	5	23	2	0	5	18
Collaborative definition of quality requirements	7	17	12	30	9	29	4	13	3	5	1	1

Let us observe the RE practice "customer communication at all levels and phases" addressing the challenge "aligning goals and perspectives within the organization", from Table 29 it is known that in total 45 responses are obtained, from these 45 respondents 14 are working in small-medium level organizations (Category A) and 31 are working in large-very large organization (Category B). For software process for quality requirements and requirement specification quality 41 responses are obtained among which large-very large organization respondents are twice than the respondents from small-medium scale organizations and this variance can be easily observed in many of the RE practices, see Table 29. Therefore, results from Table 29 depicts that the alignment practices are more often used in large-very large scale organizations, which is discussed in the literature.

Similarly, to know the variance in responses the author considered requirements practitioners as category B and other practitioners such as business analyst, quality analysts, developers/testers as category A, then the analysis was carried out, see Table 30. It is important to notice that, here respondents were allowed to choose more than one option, so the analysis is done on the basis of number of responses and not over number of respondents. Therefore, it was observed that for RE practice "cross-role requirement review" addressing challenge "cooperating successfully" has obtained 42 responses, among which 28 belong to category A and 32 belong to category B and so on.

Table 30 Variance in responses within related to respondent roles for RE practices addressing the challenges

	Aligning goals and perspectives within organization		Co-operating successfully		Requirement specification quality		V&V quality		Outsourcing of components and testing		Requirements abstraction levels	
Roles	A	B	A	B	A	B	A	B	A	B	A	B
Customer communication at all requirement phases	29	35	2	5	29	34	28	32	28	30	28	30
Development involved in detailing requirements	29	32	29	32	29	32	27	29	23	24	29	30
Cross-role requirement review	27	28	28	32	29	34	29	30	25	25	26	27
Requirements review responsibility defined	0	3	2	6	27	30	28	30	28	30	28	29
Sub system expert involved in requirement definition	28	29	27	30	30	33	27	30	26	27	29	28
Documentation of requirement definition rationale	28	29	28	30	0	5	1	4	0	1	27	26
Feature requirement documentation	1	3	0	1	29	35	29	33	1	3	1	2
Informal communication within organization	24	26	28	31	4	7	2	3	0	2	2	4
Software process for quality requirements	5	8	17	12	29	32	27	30	10	12	1	3
Structure requirement artefacts	5	7	27	31	16	19	19	20	0	2	14	15
Collaborative definition of quality requirements	20	14	28	32	20	25	9	17	5	8	0	2

The results confirm the viewpoints provided by the literature, see Table 13. As mentioned previously, from the responses we can observe that unaddressed RE practices were answered through the survey such as feature requirements documentation, informal communication within organization, software process for quality requirements, structure requirements artefacts accord to type and collaborative definition quality requirements (see Table 34).

5.6 Results from the Open Ended Questions

As mentioned in the previous section 3.7, the author has added open ended questions for some questions (see Appendix A) in order to provide additional comments and gather opinions. The open ended questions were included for knowing additional RE process factors, Organizational factors, RE practices and challenges faced during the alignment of RE and V&V, which were not specified in the literature. The responses from the respondents were collected and analyzed in order to include these results in the final list of answers for research questions.
Firstly, an open ended answers were provided for the question about RE process factors that shows impact during the alignment between RE and V&V, which were not specified in the provided list. The apprehension to pose this question was to collect the RE process factors that were not mentioned in the literature. In total 14 respondents have submitted some additional RE process factors, which were not provided in the list. Some of the respondents provided basic RE process factors such as change in requirements etc. For instance, some of the responses among them are:

"Some "Requirements Engineering" methods and notations encourage verifiable requirements. For example: Use of data modelling can be traced to database design and verified. Alternatives in Use Cases can be used to generate skeleton test cases. Unfortunately, almost any structured requirements approach may present difficulties in communicating with the business users. On the other hand, pure text descriptions, may be acceptable to the business users, but tend to be imprecise and ambiguous."

"Constantly changing requirements, Customer Expectations, Communication, Terms and Definitions that belong to the domain, Large number of documents, Complex domain, Full test coverage on all type of requirements (ISO 9126) as many of the characteristics are not that easy to test"

" *Decision made late in the requirement process" might affect negatively. Time to take decisions shorter in the whole requirement process will also show negative affect.*

"structured requirement approaches will be different from one organizational units to other units. It will be quite difficult to follow these many approaches"

Responses of each respondent was analyzed and the most discussed were chosen. They are:

- Large number of documents
- Acceptance criteria
- Decisions made late in the requirement process
- Structured requirement approaches

Secondly, respondents provided answers regarding additional organizational factors that shows the impact during the alignment between RE and V&V, which were not specified in the provided list. The apprehension to pose this question was to collect the organizational factors that are not mentioned in the literature. The respondents have provided some

responses with organizational factors, which were not provided in the list. For instance, some of the responses among them are:

"*language and cultural difference can also be considered because, we (our company) will have some of outsourcing teams in our testing phases (in specific to outsourced projects).*"

"misjudgments of some targets like time to market, design to budget will show negative impact"

Similarly, 12 respondents have submitted some organizational factors that show impact during the alignment between RE and V&V. Responses of each respondent was analyzed and the most discussed were chosen. They are:

- Language and cultural differences
- Unavailability/ shortage of SME's
- Geographical distance between the units
- Time to market

Secondly, respondents were provided open ended question to provide the challenges faced during the alignment between RE and V&V, which were not specified in the provided list. The apprehension to pose this question was to collect the challenges that are not mentioned in the literature. Respondents have submitted some responses with challenges, which were not provided in the list. For instance, some of the responses among them are:

"*splitting the requirements into smaller ones can create ambiguity and may lose main moto behind the original requirements"*

"Previous experience in the domain will effect the project drastically, if the experience is less, then the effect is negative and if the experience is more then it might benefit"

"Difficulty to find the responsible person for change in requirements"

Similarly, most of the respondents have submitted some challenges that are faced during the alignment between RE and V&V. Many of the respondents submitted some challenges, which were not presented in questionnaire, but they are gathered through literature. As mentioned earlier, challenges that commonly faced during the alignment between RE and V&V were only considered in the questionnaire[2][56]. Therefore, responses of each respondent was analyzed and the most discussed were chosen apart from the challenges identified through literature. They are:

- Shared methodology
- Familiarity with the technology being used
- Previous experience in the domain
- Difficulty to find the responsible person for change in requirements
- Delay in decisions during the change in requirements
- Splitting composite requirements into smaller ones

5.7 Summary of the Survey Results

After performing the analysis of general demographics of survey respondents, it is easily observed that 61% of the respondents are having an experience of 5 years or more in the field of requirement engineering. The level of experience of respondents within related to

requirements can influence the survey results and adds a value to the reliability of the results. From the responses it can also observed that 63% respondents are working in large and very large scale organizations, which provides necessary idea about implementation of alignment practices during the alignment between RE and V&V.
The survey results highlight unaddressed RE practices such as feature requirement documentation, informal communication within organization, same process for quality requirements and collaborative definition of quality requirements are answered, see Table 27. After detailed analysis of these results it was observed that feature requirement documentation addresses challenges such as requirement specification quality and V&V quality, informal communication within organization addresses challenges such as aligning goals and perspectives within organization and cooperating successfully and so on.
The first step of the survey is to understand the practitioner's perspective on the impact of RE process factors during the alignment. In order to achieve this, practitioners were provided with list of identified RE process factors identified through the literature and were asked to select the impact of each factor according to their perception. Based on the responses obtained the analysis was carried out. After analyzing, it was observed that RE process factors such as testability of requirements and distance between development of requirements and testing show negative impact on the alignment, whereas the source of requirement factors remain neutral. In addition to the identified list from the literature, respondents have also specified some RE process factors such as a large number of requirement documents, acceptance criteria, decisions made late in requirements, structured requirement approaches. The list of RE process factors which shows impact on alignment are categorized into positive, neutral and negative, in order of high importance to low i.e. these RE process factors are presented in decreasing order of importance, see Table 31.

Table 31 Categorized list of RE process factors presented in the order of importance

RE process factors	Positive	Neutral	Negative
Testability of requirements			X
Distance between development of requirements and testing			X
Source of requirements		X	

Similarly, respondents were provided with the list of organizational factors that will impact alignment between RE and V&V are provided. These organizational factors were gathered through literature. After analyzing the results, it was observed that organizational factors such as organizational structure, gaps in communication across different organizational units, distance in between development of requirements and test artefacts, size of organization and domain/system type will show negative impact during the alignment between RE and V&V. In addition to the identified list from the literature, respondents have also specified some organizational factors such as time to market, geographical distance between the units, unavailability of SME's and language and cultural differences. The list of organizational factors which shows impact on alignment are categorized into positive, neutral and negative, in order of high importance to low i.e. these organizational factors are presented in decreasing order of importance, see Table 32.

Table 32 Categorized list of organizational factors presented in order of importance

Organizational factors	Positive	Neutral	Negative
Distance between development of requirements and test artefacts			X
Organizational structure			X
Size of an organization			X
Gaps in communication across different organizational units			X
Domain/system type			X

Similarly, respondents are provided with the list of challenges during alignment between RE and V&V are provided. These challenges are gathered through literature. The respondents were asked to provide their level of importance based on the effect of a particular challenge during the alignment of RE and V&V. Analysis was performed based on the responses obtained. After analyzing it was observed that challenges such as managing a large document space, verifying quality requirements, time and resource availability, maintaining alignment when requirements change are most commonly and important challenges faced during the alignment between RE and V&V. In addition to the identified list from the literature, respondents have also specified some challenges such as previous experience of the domain, delay in decisions during the change in requirements, splitting composite requirements into smaller ones and familiarity with the technology being used. The challenges are provided in the decreasing order of importance based on their mean ranks obtained during statistical analysis, see Table 33.

Table 33 List of challenges presented in order of importance

Challenges
Managing a large document space
Verifying quality requirements
Time and resource availability
Keeping requirements document updated
Maintaining alignment when requirements change
Cooperating successfully
Aligning requirements and perspectives with the organizations
Tracing between requirement abstraction levels
Defining a good verification process
Defining a clear and verifiable requirements
Full test coverage
Coordinating requirements at different abstraction levels
Defining requirements at abstraction levels well matched to test cases
Out sourcing of components

Another objective of the survey is to validate the literature gathered for applying RE practices at different requirement phases. Therefore, the respondents were asked to select the RE practices that are applied at different requirement phases such as analysis, elicitation, specification and validation. The analysis was performed based on the obtained responses. After analysis of survey responses and statistical analysis customer communication at levels and in all phases of development, informal communication with in organization and same process for quality requirements are the most commonly used RE practices and are applied at all requirement phases.

Table 34 List of RE practices applied at different requirement phases

RE practices	Requirement phases			
	Elicitation	Analysis	Specification	Validation
Customer communication at all levels and in all phases of development	X	X	X	X
Involving developers and testers in detailing requirements			X	
Cross role requirement reviews		X		
Requirements review responsibilities defined		X		
Subsystem expert involved in requirements definition	X			
Documentation of requirements decision rationales			X	
Use of a customer proxy role	X			
Feature requirements documentation			X	
Informal communication within organization	X	X	X	X
Same process for quality requirements	X	X	X	X
Structure requirement artefacts accord to type			X	
Collaborative definition of quality requirements.	X			

Another objective of the survey is to validate the literature gathered for RE practices addressing different challenges. Therefore, respondents were asked to select RE practices that addresses different alignment challenges. Analysis was performed based on the obtained responses. It is important to note that the challenges that were unaddressed by RE practices are identified through survey. After analyzing it can be observed that unaddressed RE practices were answered namely feature requirements documentation, informal

communication within organization, software process for quality requirements, structure requirements artefacts accord to type and collaborative definition quality requirements. In order to obtain the more reliable results, the author has selected the options that achieved more than 70% of the responses, see Table 27. For example, in Table 27 see RE practice structure requirements artefacts accord to type has obtained 27, 28, 23 responses for addressing challenges such as requirements specification quality, V&V quality and requirements abstraction levels. Here, these options were not considered due to the fact that the response rate is <70%, see Tables 27 and 35.

Table 35 List of RE practices that addresses different challenges during the alignment between RE and V&V

Challenges / RE Practices	Aligning goals and perspectives within organization	Cooperating successfully	Requirements specification quality	V&V quality	Requirement abstraction levels	Outsourcing & offshoring of components
Customer communication at all requirement levels & phases	X		X	X	X	X
Development involved in detailing requirements	X	X	X	X		X
cross-role requirement reviews	X	X	X	X		X
Requirements review responsibilities defined			X	X		X
Sub system expert involved in requirements definition	X	X	X	X		X
Documentation of requirement decision rationale	X	X			X	
feature requirement documentation			X	X		
informal communication with in organization	X	X				
software processes for quality requirements			X	X		
structure requirement artefacts		X				
Collaborative definition of quality requirements		X	X			

5.8 Validity threats of the Survey

Four types of validity threats could affect the survey. They are external validity, internal validity, construct validity and conclusion validity[60].

External validity is the risk regarding the members of the population. The heterogeneity of the survey respondents was ensured by targeting as diverse set of respondents as possible. There might be a chance for submitting wrong responses, which might cause bias in the results of the survey. Therefore, in order to mitigate this risk, the survey link was posted in the groups of requirements engineering, requirement analyst groups, quality analyst groups and in some testing groups etc. These groups will have many practitioners and professionals from every corner of the world, which allows trusting them and will provide some inputs related to this topic.

Internal validity considers threats related to the questionnaire of the survey and the type of content, questions present in the survey. This validity might occur, when respondents may refuse to answer the survey or not comfortable in answering the survey. In order to mitigate this risk, the questionnaire was designed in a way that practitioners can easily understand it. For practitioner's convenience don't know option is provided for each open ended question, this makes practitioners comfortable to answer the required questions in the questionnaire. The author considered experience of respondents as a factor to ensure that the results obtained from the survey are reliable. However, there might be some complications by taking experience as a key factor, which is an internal validity threat to this research.

Construct validity means " *the degree to which a test measures what it claims, or purports, to be measuring*" [60]. If the questionnaire not provide any essential or necessary for the research, this type of threat might occur. If the survey is provided in an abstract way, without having any idea and if the survey contains irrelevant questions to the research topic this threat might occur. Therefore, to mitigate this threat results identified through SLR such as RE process factors, organizational factors, challenges and RE practices are given in the survey. Some of the results from the literature were not included in the questionnaire such as challenges, which will enormously increase the length of the survey and time taken to answer the survey, this might effect the number of responses. As mentioned earlier, questionnaire was tested with some practitioners to ensure the readiness and understandability of the questionnaire.

Trustworthiness and usefulness of the survey is considered as conclusion validity of the survey. In order to mitigate this risk, the responses were analyzed carefully and the results were represented using heat maps and constructed using statistical analysis. By excluding commonalties, open ended questions in the questionnaire were carefully analyzed by the author. To know whether the difference in between answers due to the experience of the respondent, a statistical analysis was conducted by considering experience within related to requirements as a confounding factor.

6 DISCUSSIONS

This section provides the analysis and discussion of the results from both SLR and the Survey parts of the study.

6.1 Research questions revisited

RQ1 and RQ1.1: The obtained list of RE practices hat facilitate alignment between RE and V&V is derived from the literature study and provided in the survey long with the requirement phases in which each practice is applied. This helps in validating the systematic literature review results and expanding possible additional RE practices. Table 36 depicts of the summarized results.

Table 36 Final list of identified RE practices applied at different requirement phases during the alignment between RE and V&V

Description	Requirement phases			
	Elicitation	Analysis	Specification	Validation
Customer communication at all levels and in all phases of development (S9_1) (S16_18)	X	X	X	X
Involving developers and testers in detailing requirements (S9_2) (S16_19)			X	
Cross role requirement reviews (S9_3) (S16_20)		X		
Requirements review responsibilities defined (S9_4)		X		
Subsystem expert involved in requirements definition (S9_5)	X			
Documentation of requirements decision rationales (S9_6)			X	
Use of a customer proxy role (S16_1)	X			
Feature requirements documentation (S16_2)			X	
Informal communication within organization (S16_4)	X	X	X	X
Same process for quality requirements (S16_6)	X	X	X	X
Structure requirement artefacts accord to type (S16_7)			X	
Collaborative definition of quality requirements. (S16_18)	X			

RQ2: This research question is intended to identify the RE process factors that influences the alignment between RE and V&V, along with their impact. The resulting RE process factors re summarized in Table 37.

The following additional RE process factors were obtained through the survey: decisions made late in requirements phases, large number of documents, structured requirement

approaches and acceptance criteria are included at end of the list along with their impact during the alignment between RE and V&V. The results obtained through survey are reliable, since 61% of the respondents are having experience more than 5 years with in related to requirements. The SLR result suggest, that RE process such as distance between development of requirements and testing and testability of requirements might have negative impact during the alignment and the same was being resulted from the survey [17] [9] [2]. Whereas, the impact of source of requirements was not discussed in the literature and from the survey it was observed as neutral (i.e. either positive nor negative).

Table 37 Final list of RE process factors and their impact during the alignment between RE and V&V

RE process factors	Positive	Neutral	Negative
Testability of requirements			X
Distance between development of requirements and testing			X
Source of requirements		X	
RE process factors identified through survey and their impact on alignment			
Decisions made late in requirement process			X
Large number of documents			X
Structured requirement approaches			X
Acceptance criteria		X	

RQ:3 The list of organizational factors hat influence RE and V&V alignment derived from the systematic literature review was provided to the survey participants. Some of the survey respondents provided additional organizational factors, which were not included in the identified list of organizational factors. The final list of organizational factors is provided in the decreasing level of importance, see Table 38.

The following additional organizational factors were obtained through survey: time to market, geographical distance between units, unavailability of SME's and language and cultural differences are included at end of the list along with their impact during the alignment between RE and V&V. The literature mentioned that the impact of some organization factors such as size of an organization, structure of organization and gaps in communication across different organizational units varies from small organizations to large organization[2]. The impact of these factors on small organization is positive whereas, negative on large organizations. The survey results suggest that the impact of these factors is negative. This is due to the fact that 63% of the survey respondents belongs to large and very large organizations.

Table 38 Final list of organizational factors and their impact during the alignment between RE and V&V

Organizational factors	Positive	Neutral	Negative
Distance between development of requirements and test artefacts			X
Organizational structure			X
Size of an organization			X
Gaps in communication across different organizational units			X

Domain/system type			X
Organizational factors identified through survey and their impact on alignment			
Time to market			X
Geographical distance between units			X
Unavailability/ shortage of SME's		X	
Language and cultural differences			X

RQ4 and RQ4.1: focused on identifying the challenges that are faced during the alignment between RE and V&V and potential RE practices that address them. The list of challenges derived from the literature was presented to survey practitioners for evaluation and commentary. Participants were asked to mark the level of occurrence or affect caused by an individual challenge and mark the provided challenges that are addressed by individual RE practices.

The literature highlights that keeping requirements document updated and maintaining alignments when requirements changes are the challenges, which occur more frequently during the alignment [2], [6], [56]. Whereas, after analyzing the results of the survey it was observed that managing a large document space and verifying quality requirements are the challenges that occur more frequently during alignment between RE and V&V. The additional challenges that were identified through the survey were not prioritized by the respondents, see Table 39.

Similarly, the list of challenges that are addressed by RE practices address is provided along with the challenges that are unaddressed in literature, see Table 40.

Table 39 Final list of challenges that are faced during the alignment between RE and V&V

Challenges
Ch23:Managing a large document space
Ch14:Verifying quality requirements
Ch22:Time and resource availability
Ch10:Keeping requirements document updated
Ch15:Maintaining alignment when requirements change
Ch6:Cooperating successfully
Ch5:Aligning goals and perspectives with the organizations
Ch18:Tracing between requirement abstraction levels
Ch12:Defining a good verification process
Ch8:Defining a clear and verifiable requirements
Ch11:Full test coverage
Ch16:Coordinating requirements at different abstraction levels
Ch25:Defining requirements at abstraction levels well matched to test cases
Ch24:Out sourcing of components
Challenges that are identified through survey
Ch25:Previous experience in the domain
Ch26:Delay in decision during the change in requirement
Ch27:Splitting composite requirements into smaller one
Ch28:Shared methodology
Ch29:Familiarity technology being used

Table 40 List of challenges that are addressed by RE practices during the alignment between RE and V&V

Challenges / RE practices	Aligning goals and perspectives within organization	Cooperating successfully	Requirements specification quality	V&V quality	Requirement abstraction levels	Outsourcing & offshoring of components
Customer communication at all requirement levels & phases	X		X	X	X	X
Development involved in detailing requirements	X	X	X	X		X
cross-role requirement reviews	X	X	X	X		X
Requirements review responsibilities defined			X	X		X
Sub system expert involved in requirements definition	X	X	X	X		X
Documentation of requirement decision rationale	X	X			X	
Challenges addressed by unaddressed RE practices through survey						
feature requirement documentation			X	X		
informal communication with in organization	X	X				
software processes for quality requirements			X	X		
structure requirement artefacts		X				
Collaborative definition of quality requirements		X	X			

7 Conclusions

RE and V&V helps in achieving efficient and successful software development in particular to the large scale organizations [3], [6], [9], [10], [13]. However, extensive coordination is needed between people, artefacts and activities for achieving alignment between RE and V&V [3]. There are many methods and techniques for linking artefacts, which includes tracing between artefacts and model-based engineering[6]. For achieving RE and V&V alignment, many companies with strong incentives apply alignment to disguise challenges including full traceability between requirements and testing [6]. This depicts the requirement of aligning artefacts along with a few more factors.

Therefore, this thesis focuses on identifying the RE process factors, organizational factors that show impact on RE and V&V alignment. Due to time constraint of the thesis, only RE process factors and organizational factors are considered. This study has also focused on the identification of challenges faced during the RE and V&V alignment along with the practices, that are used to address the identified challenges. Similarly, only RE practices are considered among the list of identified alignment practices for addressing the challenges.

The SLR served for providing answers to research questions RQ1, RQ1.1, RQ2, RQ3, RQ4 and RQ4.1. The results obtained through the literature have been used in the identification of RE practices, RE process factors, organizational factors and challenges that are faced during the alignment between RE and V&V.

The systematic literature review served as an input for the preparation of questionnaire. During the analysis, it was observed that most of the literature has focused on the identification of alignment practices and challenges faced during the alignment rather than trying to address the RE practices with the challenges. Similarly, it was interesting to note that the literature has not much focused on the impact of RE process factors and organizational factors during the alignment between RE and V&V. Therefore, the survey was conducted for identifying the impact of RE process factors, organizational factors and the occurrence or importance of each challenge identified in the literature along with the list of RE practices that address different alignment challenges. Statistical analysis was performed in order to understand the variance in results obtained through survey.

The outcome of this master thesis confirms that the impact of RE process factors such as *testability of requirements, distance between development of requirement and testing* on the RE and V&V alignment is negative. Whereas, the impact of *source of requirements* is found to be neutral (i.e. either negative nor positive), which in novelty in relation to previous work[2], [57]. Furthermore, prioritized list of RE process factors was derived from the survey. *Testability of requirements* is considered as the most important RE process factor that shows impact on alignment between RE and V&V.

The survey results were statistically analyzed to uncover potential relationships between the RE process factors and demographics of survey respondents such as role of respondents, experience within related to respondents and size of an organization. A significant relationship is found between the experience of respondents and the RE process factors ($p=0.006$, Charmer's $V= 0.672$).

Another contribution of the thesis is the identification of impact of organizational factors besides RE process factors. The majority of the survey respondents (63%) belonged to large and very large organizations, and suggested that the impact of organizational factors such as *distance between development of requirements and artefacts, organizational structure and size of an organization* was negative during the alignment between RE and V&V. The literature suggest that the impact varies from large organizations to small organizations and impact of these organizational factors on small organizations is positive whereas, negative on

large organizations[2], [6]. A statistically significant relationship was found between the size of the organization and the organizational factors (p=0.076, Charmer's V= 0.403).
Furthermore, the results from the survey also abetted in identifying important challenges during the alignment between RE and V&V. After analyzing the results of the survey it was observed that *managing a large document space* (5.89 mean rank), *verifying quality requirements* (6.24 mean rank), *time and resource availability* (6.61 mean rank) have been opted as important challenges during the alignment by the survey participants. The literature suggests that *keeping requirements documents updated and maintaining alignment between the challenges* were considered as the important challenges that occur frequently during the alignment between RE and V&V [2], [6]. Here, Friedman test was used to test the significance and the mean rank of the identified challenges, this helps in prioritizing the challenges according to their importance.
Additionally, the survey results also identified unaddressed challenges by some RE practices namely *feature requirement documentation, informal communication within organization, software processes for quality requirements, structure requirement artefacts and collaborative definition of quality requirements*. Participants of the survey have also mentioned some RE process factors, organizational factors during the alignment between RE and V&V in open-ended questions provided in the questionnaire. The list of RE process factors, organizational factors was provided along with their impact during the alignment between RE and V&V in Tables 37 and 38. Also, a final list of challenges according to their level of importance, RE practices applied at different requirement phases and challenges that are addressed by RE practices during the alignment between RE and V&V was provided, see Tables 39 and 40.

8 Future work

There is a need to investigation of other practices such as verification & validation, tracing, tools practices during the alignment between RE and V&V. After performing this, there is a chance of gathering the unaddressed challenges by the identified V&V practices. Future work should also focus on investigating the impact of V&V process factors and other context factors during the alignment between RE and V&V. In addition to this, various tools and methodologies can be found to figure out the traceability between RE and V&V.
Secondly, a case study should be performed at companies applying RE and V&V alignment practices to identify further alignment practices and thus can lead to much deeper insights. In addition to this, root cause analysis for the occurrences of each challenge that exist in implementing the alignment practices should be performed.
Moreover, one practice can address more than one challenge. Therefore, based on the planned case study it paves in finding more relation between the challenges and practices.

9 References:

[1] K. Wnuk, L. Ahlberg, and J. Persson, “On the delicate balance between RE and Testing: Experiences from a large company,” in *2014 IEEE 1st International Workshop on Requirements Engineering and Testing (RET)*, 2014, pp. 1–3.

[2] E. Bjarnason, P. Runeson, M. Borg, M. Unterkalmsteiner, E. Engström, B. Regnell, G. Sabaliauskaite, A. Loconsole, T. Gorschek, and R. Feldt, “Challenges and practices in aligning requirements with verification and validation: a case study of six companies,” *Empir. Softw. Eng.*, vol. 19, no. 6, pp. 1809–1855, Jul. 2013.

[3] D. Damian and J. Chisan, “An empirical study of the complex relationships between requirements engineering processes and other processes that lead to payoffs in productivity, quality, and risk management,” *Softw. Eng. IEEE Trans. On*, vol. 32, no. 7, pp. 433–453, 2006.

[4] B. Regnell, R. B. Svensson, and K. Wnuk, “Can We Beat the Complexity of Very Large-Scale Requirements Engineering?,” in *Requirements Engineering: Foundation for Software Quality*, B. Paech and C. Rolland, Eds. Springer Berlin Heidelberg, 2008, pp. 123–128.

[5] T. Gorschek and A. M. Davis, “Requirements engineering: In search of the dependent variables,” *Inf. Softw. Technol.*, vol. 50, no. 1–2, pp. 67–75, Jan. 2008.

[6] G. Sabaliauskaite, A. Loconsole, E. Engström, M. Unterkalmsteiner, B. Regnell, P. Runeson, T. Gorschek, and R. Feldt, “Challenges in Aligning Requirements Engineering and Verification in a Large-Scale Industrial Context,” in *Requirements Engineering: Foundation for Software Quality*, R. Wieringa and A. Persson, Eds. Springer Berlin Heidelberg, 2010, pp. 128–142.

[7] J. A. Jones, M. Grechanik, and A. Van der Hoek, “Enabling and enhancing collaborations between software development organizations and independent test agencies,” in *Proceedings of the 2009 ICSE Workshop on Cooperative and Human Aspects on Software Engineering*, 2009, pp. 56–59.

[8] Z. A. Barmi, A. H. Ebrahimi, and R. Feldt, “Alignment of Requirements Specification and Testing: A Systematic Mapping Study,” in *2011 IEEE Fourth International Conference on Software Testing, Verification and Validation Workshops (ICSTW)*, 2011, pp. 476–485.

[9] J. Kukkanen, K. Vakevainen, M. Kauppinen, and E. Uusitalo, “Applying a Systematic Approach to Link Requirements and Testing: A Case Study,” in *Software Engineering Conference, 2009. APSEC ’09. Asia-Pacific*, 2009, pp. 482–488.

[10] E. J. Uusitalo, M. Komssi, M. Kauppinen, and A. M. Davis, “Linking Requirements and Testing in Practice,” in *16th IEEE International Requirements Engineering, 2008. RE ’08*, 2008, pp. 265–270.

[11] B. H. C. Cheng and J. M. Atlee, “Research Directions in Requirements Engineering,” in *2007 Future of Software Engineering*, Washington, DC, USA, 2007, pp. 285–303.

[12] R. Watkins and M. Neal, “Why and how of requirements tracing,” *IEEE Softw.*, vol. 11, no. 4, pp. 104–106, Jul. 1994.

[13] D. Damian, J. Chisan, L. Vaidyanathasamy, and Y. Pal, “Requirements Engineering and Downstream Software Development: Findings from a Case Study,” *Empir. Softw. Eng.*, vol. 10, no. 3, pp. 255–283, Jul. 2005.

[14] H. Post, C. Sinz, F. Merz, T. Gorges, and T. Kropf, “Linking Functional Requirements and Software Verification,” in *Requirements Engineering Conference, 2009. RE ’09. 17th IEEE International*, 2009, pp. 295–302.

[15] L. O. Lobo and J. D. Arthur, “Local and Global Analysis: Complementary Activities for Increasing the Effectiveness of Requirements Verification and Validation,” in

Proceedings of the 43rd Annual Southeast Regional Conference - Volume 2, New York, NY, USA, 2005, pp. 256–261.
[16] M. Unterkalmsteiner, R. Feldt, and T. Gorschek, "A Taxonomy for Requirements Engineering and Software Test Alignment," *ACM Trans Softw Eng Methodol*, vol. 23, no. 2, pp. 16:1–16:38, Apr. 2014.
[17] E. Bjarnason, M. Unterkalmsteiner, E. Engström, and M. Borg, "An Industrial Case Study on Test Cases as Requirements," in *Agile Processes, in Software Engineering, and Extreme Programming*, C. Lassenius, T. Dingsøyr, and M. Paasivaara, Eds. Springer International Publishing, 2015, pp. 27–39.
[18] E. Bjarnason, K. Smolander, E. Engström, and P. Runeson, "Alignment Practices Affect Distances in Software Development: A Theory and a Model," in *Proceedings of the 3rd SEMAT Workshop on General Theories of Software Engineering*, New York, NY, USA, 2014, pp. 21–31.
[19] B. Randell, "Towards a methodology of computing system design," in *NATO working conference on software engineering*, 1968, pp. 204–208.
[20] J. Cleland-Huang, C. K. Chang, and M. Christensen, "Event-based traceability for managing evolutionary change," *IEEE Trans. Softw. Eng.*, vol. 29, no. 9, pp. 796–810, Sep. 2003.
[21] O. C. Z. Gotel and A. C. W. Finkelstein, "An analysis of the requirements traceability problem," in *, Proceedings of the First International Conference on Requirements Engineering, 1994*, 1994, pp. 94–101.
[22] B. Ramesh, "Factors influencing requirements traceability practice," *Commun. ACM*, vol. 41, no. 12, pp. 37–44, 1998.
[23] A. C. Dias Neto, R. Subramanyan, M. Vieira, and G. H. Travassos, "A survey on model-based testing approaches: a systematic review," in *Proceedings of the 1st ACM international workshop on Empirical assessment of software engineering languages and technologies: held in conjunction with the 22nd IEEE/ACM International Conference on Automated Software Engineering (ASE) 2007*, 2007, pp. 31–36.
[24] S. Jalali and C. Wohlin, "Systematic Literature Studies: Database Searches vs. Backward Snowballing," in *Proceedings of the ACM-IEEE International Symposium on Empirical Software Engineering and Measurement*, New York, NY, USA, 2012, pp. 29–38.
[25] C. Nebut, F. Fleurey, Y. Le Traon, and J.-M. Jezequel, "Automatic test generation: A use case driven approach," *Softw. Eng. IEEE Trans. On*, vol. 32, no. 3, pp. 140–155, 2006.
[26] T. Yue, L. C. Briand, and Y. Labiche, "A systematic review of transformation approaches between user requirements and analysis models," *Requir. Eng.*, vol. 16, no. 2, pp. 75–99, 2011.
[27] B. Hasling, H. Goetz, and K. Beetz, "Model based testing of system requirements using UML use case models," in *Software Testing, Verification, and Validation, 2008 1st international conference on*, 2008, pp. 367–376.
[28] B. Regnell, P. Runeson, and C. Wohlin, "Towards integration of use case modelling and usage-based testing," *J. Syst. Softw.*, vol. 50, no. 2, pp. 117–130, 2000.
[29] B. Regnell and P. Runeson, "Combining Scenario-based Requirements with Static Verification and Dynamic Testing.," in *REFSQ*, 1998, pp. 195–206.
[30] L. Cao and B. Ramesh, "Agile requirements engineering practices: An empirical study," *Softw. IEEE*, vol. 25, no. 1, pp. 60–67, 2008.
[31] G. Melnik, F. Maurer, and M. Chiasson, "Executable Acceptance Tests for Communicating Business Requirements: Customer Perspective," in *AGILE Conference*, Los Alamitos, CA, USA, 2006, vol. 0, pp. 35–46.

[32] S. Keele, “Guidelines for performing systematic literature reviews in software engineering,” in *Technical report, Ver. 2.3 EBSE Technical Report. EBSE*, 2007.
[33] C. Wohlin, “Guidelines for Snowballing in Systematic Literature Studies and a Replication in Software Engineering,” in *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, New York, NY, USA, 2014, pp. 38:1–38:10.
[34] B. Kitchenham, O. Pearl Brereton, D. Budgen, M. Turner, J. Bailey, and S. Linkman, “Systematic literature reviews in software engineering – A systematic literature review,” *Inf. Softw. Technol.*, vol. 51, no. 1, pp. 7–15, Jan. 2009.
[35] B. Kitchenham, R. Pretorius, D. Budgen, O. Pearl Brereton, M. Turner, M. Niazi, and S. Linkman, “Systematic literature reviews in software engineering – A tertiary study,” *Inf. Softw. Technol.*, vol. 52, no. 8, pp. 792–805, Aug. 2010.
[36] J. Webster and R. T. Watson, “Analyzing the past to prepare for the future: Writing a literature review,” *Manag. Inf. Syst. Q.*, vol. 26, no. 2, p. 3, 2002.
[37] B. A. Kitchenham, T. Dyba, and M. Jorgensen, “Evidence-Based Software Engineering,” in *Proceedings of the 26th International Conference on Software Engineering*, Washington, DC, USA, 2004, pp. 273–281.
[38] W. Hayes, “Research synthesis in software engineering: a case for meta-analysis,” in *Software Metrics Symposium, 1999. Proceedings. Sixth International*, 1999, pp. 143–151.
[39] J. Miller, “Can results from software engineering experiments be safely combined?,” in *Software Metrics Symposium, 1999. Proceedings. Sixth International*, 1999, pp. 152–158.
[40] “C. Knisely and K. Knisely, Engineering Communication. Cengage Learning, 2014.”
[41] H. R. Jennie Popay, “Guidance on the conduct of narrative synthesis in systematic reviews: A product from the ESRC Methods Programme,” 2006.
[42] M. Ivarsson and T. Gorschek, “A method for evaluating rigor and industrial relevance of technology evaluations,” *Empir. Softw. Eng.*, vol. 16, no. 3, pp. 365–395, 2011.
[43] H. Munir, K. Wnuk, and P. Runeson, “Open innovation in software engineering: a systematic mapping study,” *Empir. Softw. Eng.*, pp. 1–40, Apr. 2015.
[44] J. W. Creswell, *Qualitative inquiry and research design: Choosing among five approaches*. Sage, 2012.
[45] N. Malhotra and M. Peterson, “Basic Marketing Research; a decision-making approach,” *N. J.*, vol. 7458, 2006.
[46] T. Punter, M. Ciolkowski, B. Freimut, and I. John, “Conducting on-line surveys in software engineering,” in *2003 International Symposium on Empirical Software Engineering, 2003. ISESE 2003. Proceedings*, 2003, pp. 80–88.
[47] B. Kitchenham and S. L. Pfleeger, “Principles of survey research part 4: questionnaire evaluation,” *ACM SIGSOFT Softw. Eng. Notes*, vol. 27, no. 3, pp. 20–23, 2002.
[48] B. E. Hayes, *Measuring customer satisfaction: Survey design, use, and statistical analysis methods*. ASQ Quality Press, 1998.
[49] W. K. Kirchner, “Designing and Conducting Survey Research: A Comprehensive Guide,” *Pers. Psychol.*, vol. 46, no. 2, p. 443, 1993.
[50] L. M. Rea and R. A. Parker, *Designing and conducting survey research: A comprehensive guide*. John Wiley & Sons, 2014.
[51] “IBM - SPSS software - Sweden,” 08-Jun-2015. [Online]. Available: http://www-01.ibm.com/software/se/analytics/spss/. [Accessed: 23-Aug-2015].
[52] N. Golafshani, “Understanding Reliability and Validity in Qualitative Research,” *Qual. Rep.*, vol. 8, no. 4, pp. 597–606, Dec. 2003.

[53] P. Runeson, M. Host, A. Rainer, and B. Regnell, *Case study research in software engineering: Guidelines and examples*. John Wiley & Sons, 2012.
[54] R. Wieringa, N. Maiden, N. Mead, and C. Rolland, "Requirements engineering paper classification and evaluation criteria: a proposal and a discussion," *Requir. Eng.*, vol. 11, no. 1, pp. 102–107, 2006.
[55] R. M. Belbin, *Team Roles at Work*. Routledge, 2012.
[56] J. Larsson and M. Borg, "Revisiting the challenges in aligning RE and V amp;V: Experiences from the public sector," in *2014 IEEE 1st International Workshop on Requirements Engineering and Testing (RET)*, 2014, pp. 4–11.
[57] J. Metsa, M. Katara, and T. Mikkonen, "Testing Non-Functional Requirements with Aspects: An Industrial Case Study," in *Seventh International Conference on Quality Software, 2007. QSIC '07*, 2007, pp. 5–14.
[58] B. Kitchenham and S. L. Pfleeger, "Principles of survey research: part 5: populations and samples," *ACM SIGSOFT Softw. Eng. Notes*, vol. 27, no. 5, pp. 17–20, 2002.
[59] D. W. Zimmerman and B. D. Zumbo, "Relative power of the Wilcoxon test, the Friedman test, and repeated-measures ANOVA on ranks," *J. Exp. Educ.*, vol. 62, no. 1, pp. 75–86, 1993.
[60] W. M. Trochim and J. P. Donnelly, "Research methods knowledge base," 2001.

10 Appendix A: Survey Questionnaire

Hello,

I am Srinivasu Akkineni pursuing Master Thesis in Software Engineering at Blekinge Institute of Technology, Sweden. As a part of my Master Thesis, this research is conducted to understand the influence of requirements engineering practices, process factors and organizational factors during the alignment between requirement engineering (RE) and verification validation (V&V). This research primarily aims at understanding the implementation of RE practices at different Phases and influence of factors during the alignment. The research also intends to identify the RE practices applied for addressing the alignment challenges, the challenges faced during alignment between RE and V&V.

This Questionnaire is a part of an extensive survey that is designed to understand the perception of practitioners in the implementation of alignment practices and influence of factors during the alignment between RE and V&V.

This Questionnaire can be completed by any software practitioner, e.g.: Requirement analyst, Requirement manager, Quality analyst, Business analyst, Team Leader, Tester, Test lead, Requirements lead or Researcher in aligning RE and V&V, who has experience in practicing Software Development using alignment practices.

I request you to kindly participate in this survey by answering the questionnaire which takes around 8-12 minutes of your time. I would also request you to kindly forward the questionnaire link to other members of your software groups or the organization in which you work, and encourage them to participate as well. All your responses would be kept strictly confidential.

Thank you very much in advance for your co-operation and participation in this survey.

1. Geographical location of your organization

2. Name of your organization

3. Size of your organization

   Less than 50

   51-250

   251-1000

   1001-5000

   5001-10000

   More than 10000

4. Role in your organization

   Requirement analyst

   Business analyst

   Quality analyst

   Developer/tester

   Project manager

   Team leader

Requirements engineer

Requirements manager

Other

5. Work experience within related to requirements

   Less than 1 year

   1-2 years

   3-5 years

   5-7 years

   7-10 years

   10-15 years

   More than 15 years

6. Based on the experience in your organization, please specify the impact of RE process factors during the alignment between RE and V&V (select only one option for each row)

	Positive	Neutral	Negative	Don't know
Source of requirements (Bespoke, market driven, outsourced)				
Distance between development of requirement and testing				
Testability of requirements				

7. Please specify any RE process factors and their impact which were not specified in the previous list

8. Based on the experience in your organization, please specify the impact of organizational factors during the alignment between RE and V&V.

	Positive	Neutral	Negative	Don't know
Organizational structure				

Gaps in communication across different organizational units				
Distance in between development of requirements and test artefacts				
Size of an organization				
Domain/system type				

9. Please specify any organizational factors and their impact, which were not specified in the previous list

10. Based on the experience in your organization, which RE practices are applied at different requirement phases

Description	Requirement phases			
	Elicitation	Analysis	Specification	Validation
Customer communication at all requirement levels and phases.				
Development involved in detailing requirements				
Cross role requirements reviews				
Requirements review responsibilities defined				
Subsystem expert involved in requirements definition				
Documentation of requirements decision rationales				
Use of a customer proxy role				
Feature requirements documentation				
Informal communication within organization				

Same process for quality requirements				
Structure requirement artefacts accord to type				
Collaborative definition of quality requirements.				

11. Please specify if the following challenges are faced in an organization during the alignment between RE and V&V. Please specify the level of occurrence

	High	Medium	Low
Aligning requirements and perspectives within organization			
Co-operating successfully			
Defining clear and verifiable requirements			
Keeping requirements document updated			
Full test coverage			
Defining a good verification process			
Verifying quality requirements			
Maintaining alignment when requirements change			
Defining requirements at abstraction level well matched to test cases			
Co-coordinating requirements at different abstraction levels			

Tracing between requirements abstraction levels			
Time and resource availability			
Managing a large document space			
Outsourcing of components			

12. Please specify any other challenges and grade their importance, which were not specified in the previous list

13. Based on the experience in your organization, which RE practices will address the following challenges

    Requirement specification quality include challenges such as Defining clear and verifiable requirements, defining complete requirements, keeping requirements document updated.

    VV quality include challenges such as full test coverage, defining a good verification process, verifying quality requirements

Challenges / RE Practices	Aligning goals and perspectives within organization	Cooperating successfully	Requirements specification quality	V&V quality	Requirement abstraction levels	Outsourcing & offshoring of components
Customer communication at all requirement levels & phases						
Development involved in detailing requirements						
cross-role requirement reviews						
Requirements review responsibilities defined						
Sub system expert involved in requirements definition						
Documentation of requirement decision rationale						
feature requirement documentation						
informal communication with in organization						
software processes for quality requirements						
structure requirement artefacts						
Collaborative definition of quality requirements						

14. Please specify additional RE practices if any and specify which challenges they address, which are not specified in the above list

15. Please provide your email address if you wish to have the survey results.

11 Appendix B: Rigor and Relevance Scores

Study ID	RIGOR			Rigor sum	RELEVANCE				Relevance sum
	Context	Study Design	Validity		User/ Subject	Scale	RM	Context	
S2	1	1	0	2	1	1	1	1	4
S3	1	.5	1	2.5	1	1	1	1	4
S4	1	1	0	2	1	1	1	1	4
S5	1	1	0	2	1	1	1	0	3.5
S7	1	1	0	2	1	1	1	1	4
S8	1	.5	0	1.5	1	0	1	1	3.5
S9	1	1	1	3	1	1	1	1	4
S10	1	.5	1	2.5	1	1	0	1	3
S11	1	.5	0	1.5	1	1	1	.5	3.5
S12	1	.5	0	1.5	1	1	1	.5	3.5
S13	.5	.5	0	1	0	0	1	1	2
S14	1	.5	0	1.5	.5	0	1	1	2.5
S15	.5	.5	0	1	.5	1	1	0	2.5
S16	1	1	.5	2.5	.5	1	1	1	3.5
S17	.5	.5	0	1	0	1	0	0	1
S19	1	.5	0	1.5	.5	1	0	1	1.5
S20	1	.5	0	1.5	0	1	0	0	1

12 Appendix C: Quality assessment of secondary studies

Study ID	Methodology clearly specified	Motivation and method appropriateness	Results properly specified	Validity threats clearly specified
S1	Yes	Yes	Yes	Yes
S15	Yes	Partially	Partially	No

13 Appendix D: Rigor and Relevance description

Rigor:

Context(C):

If context described to the scope of the study, where it can be compared to other settings [42]. In particular, it explains subject type (such as graduate, undergraduate, professional, researcher), development methodology and experience, duration of the observations. If all the listed factors are discussed, then C is evaluated to 1. If any of these factors are missing in the study, then C is evaluated to 0.5. If no description of context to the scope of study is provided, then C is evaluated to 0.

Design (D):

The research design explained is well enough for a reader to understand [42]. In particular, if the study describes outcome variables, treatments, measurement criteria, sampling and number of subjects then D is evaluated to 1. If any of these factors related to design and data collection are missing in the study, then D is evaluated to 0.5. If no description of design is provided, then D is evaluated to 0.

Validity threats (V):

If different type of validity (i.e. External, internal, construct and conclusion validity) is discussed then, V is evaluated to 1. Medium description: If subsets of relevant threat categories are highlighted then, V is evaluated to 0.5. Weak description: If no description of study on validity is discussed then, V is evaluated to 0.

Relevance:

Users/subjects (U):

If the subjects/users taken into account are industry professionals then, U is evaluated to 1. If the subjects/users taken into the account are master or graduated students then, U is evaluated to 0.5. If the subjects/users taken into the account are bachelor/undergrad students or info is missing then, U is evaluated to 0.

Scale (S):

If an industrial size application is considered then, S is assessed to 1. If an industrial size application is not considered then, S is evaluated to 0.

Research Methodology (RM):

If the chosen research method is related to real world situations with relevance for practitioners (case study, industry interviews, action research, and surveys/interviews, experiment investigating a real problem). If the study belongs to any of these research methodologies then, RM is evaluated to 1. If there is any usage of lab experimentation (software/subjects) or missing information then, RM is evaluated to 0.

Context (C):

If a study is performed in an industrial setting or matches real world setting then, C is evaluated to 1. If a study is performed in artificial setting (e.g. labs) or do not match to real world situations then, C is evaluated to 0.

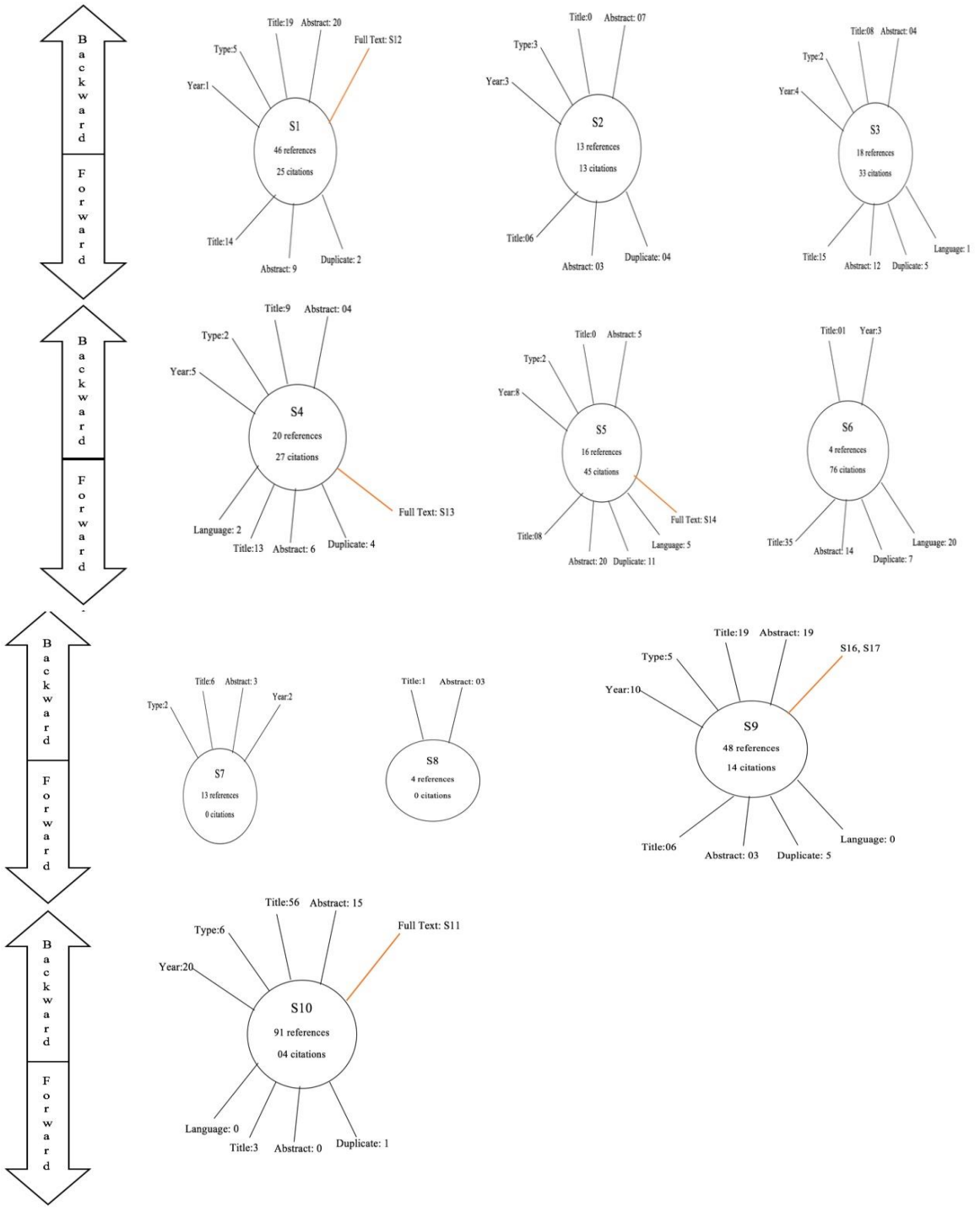
14 Appendix E: Alignment practices identified through SLR

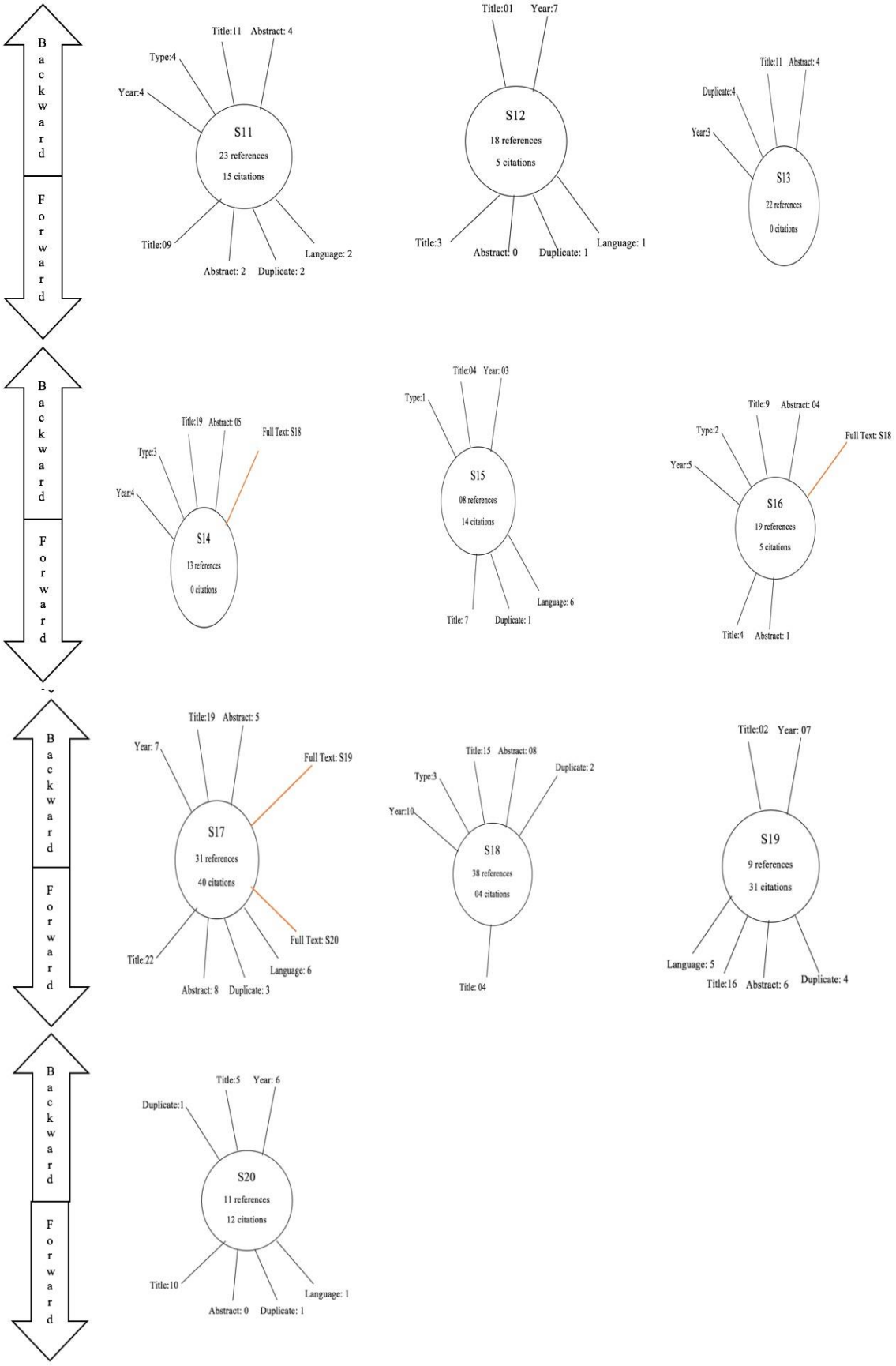
Identified From	Discussed practices
S5	• Early tester participation (S5_1) • Testers participation in requirement review(S5_2) • Test traceability to requirements(S5_3) • Linking testers with requirements owners(S5_4) • Requirement suggestion by testers(S5_5)
S2	• Communication(S2_1) • Metrics and visibility(S2_2) • Roles & responsibilities(S2_3) • Review teams(S2_4) • Review requirements(S2_5) • Change control tools(S2_6)
S1	• Involving testers during project plan (S1_1) • Requirement review (S1_2)
S9	• Customer communication at all requirement levels and phases(S9_1) • Development involved in detailing requirements(S9_2) • Cross role requirement reviews(S9_3) • Requirement reviews responsibilities defined(S9_4) • Subsystem expert involved in requirements definition(S9_5) • Documentation of requirement decision rationales(S9_6) • Test cases reviewed against requirements(S9_7) • Acceptance test cases defined by customer(S9_8) • Product manager review prototypes(S9_9) • Management base launch decision on test report(S9_10) • User/customer testing(S9_11) • Early verification start(S9_12) • Independent testing(S9_13) • Testers re-use customer feed back from previous projects(S9_14) • Training off-shore testers(S9_15) • Process for requirement change involving V&V(S9_16) • Product-line requirements practices(S9_17) • Process enforcement(S9_18) • Document level traces(S9_19) • Requirements-test case traces(S9_20) • Test cases as requirements(S9_21) • Same abstraction level for requirements and test specs(S9_22) • Traceability responsibility role (S9_23) • Tool support for requirement and testing(S9_24) • Tool support for requirements-test cases tracing(S9_25) • Alignment metrics(S9_26) • Job rotation(S9_27)
S16	• Use of a customer proxy role(S16_1)

	• Feature requirements documentation(S16_2) • Product manager physically present to developers & testers(S16_3) • Informal communication within organization(S16_4) • Product manager involved in development project. (S16_5) • Same process for QR's(S16_6) • Structure requirements artefacts that accord to type(S16_7) • Collaborative definition of quality requirements(S16_8) • Early test involvement in development projects(S16_9) • Feature based test plan(S16_10) • Separate testing team for quality requirements(S16_11) • Test impact analysis(S16_12) • Close cooperation between test and development unit and roles(S16_13) • Conceptual tracing(S16_14) • Traces between people/roles(S16_15) • Incremental development(S16_16) • Small-scale development(S16_17) • Customer communication at all levels and phases(S16_18) • Development involved in detailing requirements(S16_19) • Cross-role requirement reviews(S16_20) • Test cases reviewed against requirements(S16_21) • Product manager reviews prototype(S16_22) • User/customer testing(S16_23) • Independent testing(S16_24) • Testers re-use customer feedback(S16_25) • Process changes for requirements change involving test(S16_26) • Product line requirement practices(S16_27) • Document level traces(S16_28) • Requirements-test case traces(S16_29) • Test cases as requirements(S16_30) • Tool support for requirements and testing(S16_31) • Tool support of requirements-test case tracing(S16_32)
S14	• A De facto practice (S14_1) • TCR practice through behavior driven development tool (S14_2)

15 Appendix F: Figures for Backward and Forward snowballing

In these figures "orange" colored line represents included articles and "black" colored line indicates the excluded articles based on their title, type of publication, published year, abstract, language and duplicates. But, the studies that are already chosen in start set or during iterations, were considered as duplicates.




Backward
Forward
Title:11
Abstract: 4
Type:4
Year:4
S11
23 references
15 citations
Title:09
Abstract: 2
Duplicate: 2
Language: 2
Title:01
Year:7
S12
18 references
5 citations
Title:3
Abstract: 0
Duplicate: 1
Language: 1
Title:11
Abstract: 4
Duplicate:4
Year:3
S13
22 references
0 citations
Title:19
Abstract: 05
Full Text: S18
Type:3
Year:4
S14
13 references
0 citations
Title:04
Year: 03
Type:1
S15
08 references
14 citations
Title: 7
Duplicate: 1
Language: 6
Title:9
Abstract: 04
Type:2
Full Text: S18
Year:5
S16
19 references
5 citations
Title:4
Abstract: 1
Title:19
Abstract: 5
Year: 7
Full Text: S19
S17
31 references
40 citations
Full Text: S20
Title:22
Abstract: 8
Duplicate: 3
Language: 6
Title:15
Abstract: 08
Duplicate: 2
Type:3
Year:10
S18
38 references
04 citations
Title: 04
Title:02
Year: 07
S19
9 references
31 citations
Language: 5
Title:16
Abstract: 6
Duplicate: 4
Title:5
Year: 6
Duplicate:1
S20
11 references
12 citations
Title:10
Abstract: 0
Duplicate: 1
Language: 1

16 Appendix G: Rejoinder

Suggested changes	Action taken at
Repetitive statements (such as in introduction at page number 8, you have written quality problems and delays with quality and functionality of software, what does delays with quality mean?	Re phrased the whole sentence as "In large scale software development, weak co-ordination between RE and V&V can lead to ineffective development, quality problems and delays functionality of the software"
it is better if the author indicates a background work such as what exactly does the author consider in verification and validation activities and RE phases i.e. elicitation, analysis, specification etc.	Whole V&V activities are considered along with all RE phases and it was stated in the beginning paragraph of the thesis. No need to mention it again.
The author has to explain a brief note about what Figure 1 actually depicts.	Figure 1 is described briefly in section 2, paragraph 3.
In related work, it is better to indicate what are the RE practices, process factors and organizational factors being dealt by various authors and how they differ?	In section 2, 7th paragraph was added to give an overview on organizational and process factors, practices.
In Table 3, it was indicated that the study type, research methods was being mapped with only two RQ's i.e. RQ1 and RQ4. Why the other two RQ's were not considered?	Corrected the whole table 3 required changes are made.
Why just few of the RE practices from Table 12 are considered for categorization and why the others were left out? Is there any strong claim? If so, reference?	It was already discussed in section 4.6. Stating that only RE are considered in the whole identified practices and required references were given.
In page number 48, it was stated that "As mentioned by [S8], the influence of context factors to achieve the alignment between RE and V&V and shift of balance due to influence of these factors can be explored", what does it actually mean? Is it the author of [S8] claim or thesis author's?	Corrected the sentence formation as "Wnuk et al. [S8] mentioned that the influence of additional factors to achieve alignment between RE and V&V and shift of balance due to influence of these factors can be explored" for better understanding of the reader.
Check with redundancy, the author repeats the same claims again and again, for example: the author have listed the summary of survey results in one section and listed out a lot of tables and the same was being said during answering the research questions. In addition in page number 9, it was stated as "This study calls for investigating and exploring which additional factors may influence the balance between RE and V&V" and the same claim was repeated in the next paragraph.	some tables are deleted to reduce the redundancy of the document. It is important to notice that there is a difference between the tables mentioned in section 5.7 and section 6.1. Repeated sentence was deleted in section 1.
It is unclear for a reader to understand why few of the RE practices such as test cases reviewed against requirements, process for requirement change involving V&V and product-line requirements practices were not considered furthermore for categorizing.	product-line requirements, process for requirement change involving V&V practices are categorized under change practices and Test cases reviewed against requirements, is categorized under the validation practices [S9]. In this thesis only RE practices are considered.
References are not clearly indicated, For example, the author states that "In [31], the challenges with database searches are mentioned such as etc." Instead it is better to state that XXX et al. [Reference number] stated that and write the claim stated by author.	Corrected as " Wohlin et al.[33] discussed the challenges such as etc." in section 3.2
Tables not according to the template i.e. size of the table exceeds the actual space (Example Table 21).	Re-sized the tables 21, 36,37,38,39,26,24,27.

In page number 22, it was stated that "Since an individual researcher does the study selection" What does that mean?	This sentence was changed into "since the author carried out the study selection" for better understanding of the reader.
During backward and forward snowballing iterations, rather than mentioning the number of papers being expelled due to name, publication type etc. It is better to indicate with respect to each of the paper in a tabular form and can list them in Appendix for a reader to clearly understand the actual figures.	Added in Appendix F. But, instead of table author has drawn diagrams for better understanding of reader.
In page number 76, it was stated that an option don't know was provided in open-ended question. How can the author provide an option in open-ended question?	It was changed as " option don't know was provided in closed ended question"
Few grammatical errors can be checked in the document by re-reading. For example, in page number 63, it was written as multiple lections rather than multiple selections etc.	Corrected as multiple selections.
The terms literature review and Systematic Literature review were frequently used and is typical for a reader to understand which research method was used.	Re checked the whole document and required changes are made e.g. In section 3.2, 3.5.
The author has mentioned model-based engineering in conclusions and stated it as a method or technique In general model based engineering is an approach to engineering that holds great promise for addressing the increasing complexity of systems, and systems of system.	Changed as model based testing. By mistakenly it was written as engineering. Required reference is provided for that claim.
Add some sentences about why traceability is not included in RE practices (Supervisor comment)	In page 43, a paragraph about not considering traceability as RE practices is written.
Add how you have carried out manual analysis for survey results (Examiner comment)	Few lines about "how manual analysis was carried out was written in the document in sections 5.3, 5.4 and 5.5" before starting the analysis of survey results.
Why structured requirement approaches show negative impact on alignment (Examiner comment)	Actually this was obtained through open-ended question, that was posed in the questionnaire. Required statements are added in section 5.6 at the end of first paragraph.