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Decision Support System for Risk Assessment and Management Strategies in Distributed Software Development

ADEEL ASLAM[1], NAVEED AHMAD[1], TANZILA SABA[2], ABDULAZIZ S. ALMAZYAD[3,4], AMJAD REHMAN[3,4], ADEEL ANJUM[1], AND ABID KHAN[1]

[1]Department of Computer Science, COMSATS Institute of Information Technology, Islamabad 44000, Pakistan
[2]College of Computer and Information Sciences, Prince Sultan University, Riyadh 11586, Saudi Arabia
[3]College of Computer and Information Sciences, Al-Yamamah University, Riyadh 11512, Saudi Arabia
[4]King Saud University, Riyadh 11451, Saudi Arabia

Corresponding author: Naveed Ahmad (naveedahmad@comsats.edu.pk)

ABSTRACT Risk management in distributed software development (DSD) is a well-researched area, providing different methods for assessing risks and suggesting control strategies. However, some of these methods are narrow in scope, only considering few risks, and are too complex to be used in practice whereas others provide many rules and guidelines which are often implicit. Moreover, the knowledge related to risks in DSD is scattered over different publications which make it difficult to find relevant information to be used in practice. This research aims to develop an automated decision support system to aid practitioners in assessing risks and deciding on suitable control strategies. In order to construct the knowledge base for the proposed decision support system, a systematic literature review (SLR) is conducted. Results of SLR are used to identify required questions, options and set of rules to implement our decision support system (DSS). In total 80 studies were identified from which 49 aspects, 53 questions, and a set of rules are extracted. DSS is evaluated through multiple case studies. The results indicate that the developed DSS supports decision-making process in risk assessment and selection of control strategy.

INDEX TERMS Distributed software development, decision support system, risk analysis.

I. INTRODUCTION

Advancement in telecommunication leads software development process from traditional co-located development to offshore, which is termed as distributed software development (DSD). In DSD, companies or organizations shift some of their software development processes to other countries, where required skills are less costly. This has been embraced by various multinational companies like IBM, Siemens, Microsoft etc., where these companies have subsidiary sites in different countries [1]–[3]. Some of the benefits of DSD include: shorter time to market, follow the sun (FTS) strategy for organizations, saving cost and access to the larger and talented pool of resources [2]–[4].

Despite its various obvious benefits, there are numerous challenges associated with this type of development such as linguistic, cultural and temporal distances [3], [4]. These distances have a negative impact on communication, coordination and knowledge sharing among organization sites. Additional risks must also be considered, such as scope creep, requirement misunderstanding, quality issues and delay in final product [3], [5]–[8]. In order to overcome these risks, there should be effective risk management practices in place.

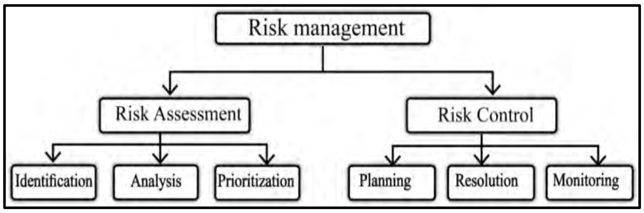


FIGURE 1. Risk management process.

According to Boehm's software risk management model [8], risk management is divided into two primary processes: 1) risk assessment; and 2) risk control, as shown in Fig. 1. These are then further divided into sub processes. The first sub process for risk assessment is risk identification, whose purpose is to identify possible threats which can

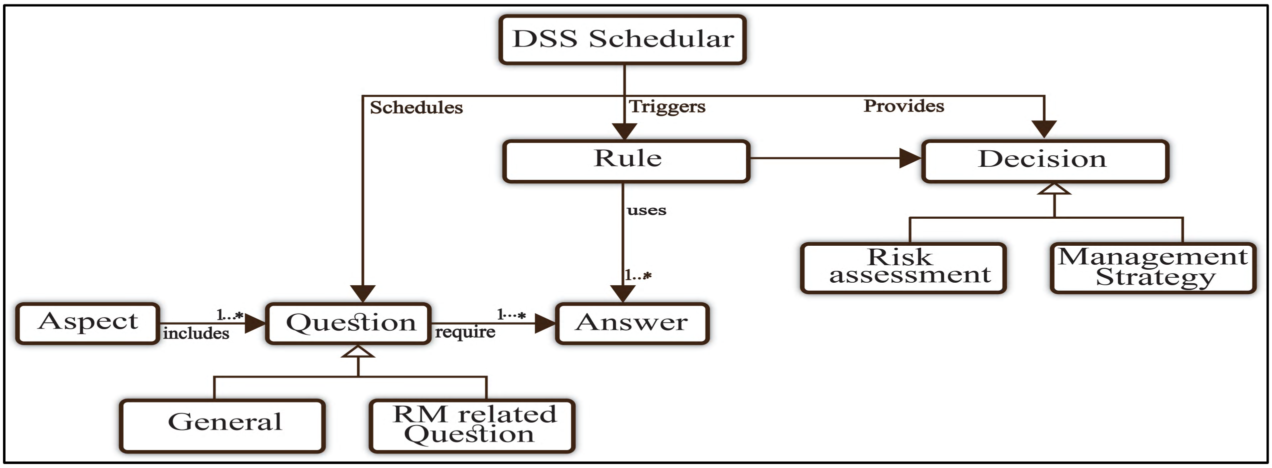


FIGURE 2. **Decision support model.**

occur during the development process. Secondly, analysis of identified risks by determining the likelihood of occurrence and probability impact of these factors. Analysis results can be used to produce a rank ordering of identified risks. Risk control subprocesses consist of risk management planning, risk resolution, and risk monitoring. In risk management planning, identified risks factors are addressed by using one of the following risk response strategies [10], [11]. These are risk avoidance, risk tolerance, risk mitigation and risk acceptance. So it can be said that when managing risks, two different decisions need to be taken. Firstly, prioritizing which identified risks has more impact on project failure. Secondly, deciding on an appropriate risk response strategy.

Risk management in DSD is a well-researched area, and the literature provides several approaches for risk assessment and discusses useful guidelines for controlling these risks. However, problem is that either researchers have only considered a limited number of risks [12] or provided generic framework without considering contextual factors of companies [1], [3]. Another issue is that these rules and guidelines are either implicit or spread across different publication. Processing upon them manually is not an easy task, requiring experience and a lot of knowledge. Hence, for decision making these studies do not aid practitioners. To overcome these challenges there is a need to accumulate these guidelines and rules and then provide automated support which can be beneficial for decision making.

In this paper, a decision support model (DSM), inspired from [13], with corresponding decision support system (DSS) is developed (**Fig. 2**). The aim is to support practitioners in decision making for risk assessment and selection of management strategy in DSD. Proposed DSM has a scheduler which presents set of questions to the decision maker. These questions aims are used to assess different risk factor and select of suitable management strategy. Answers are triggered against each question. This is enabled through a set of rules. In order to build the proposed DSS, a systematic literature review (SLR) targeting risk assessment and management strategies in DSD is conducted. Secondly, based on the output of SLR required questions, rules, and guidelines are extracted. These questions, rules, and guidelines are used to implement the DSS. Finally, DSS is empirically evaluated using different case studies from literature and industry.

Scientific approach followed by this study is inspired by the study of Tüzün *et al.*., [13] who emperically evalualte DSS for Software Product Line Engineering adoption. Rest of the paper is organized as follow. Section II provides the result of SLR. In section III, we introduce the DSS. Section IV, demonstrates the selection of multiple case studies. Section V discusses the results of DSS on selected case studies. Section VI relates the proposed DSS to similar work in distributed software development literature. Finally, section VII concludes.

II. SYSTEMATIC LITERATURE REVIEW

A. STUDY SELECTION AND ANALYSIS

To obtain required knowledge for developing the DSS for risk management in DSD, an SLR in accordance with the guidelines suggested by Kitchenham and Charter [14] is conducted. In this scenario following research questions are answered.

RQ1: What are the existing approaches for risk assessment in Distributed Software development (DSD)?

RQ2: What are the risk management strategies to overcome identified risks factors in Distributed Software Development (DSD)?

RQ3: What are the factors (aspects and risk factors) that have an impact on decision-making during risk management in Distributed Software development (DSD)?

RQ4: What kind of questions and rules can be used for decision making when assessing risks and selecting management strategies?

The following steps were used to form the search string.

1) Derivation of primary terms from the research questions.

2) Identifies synonyms and alternative spellings for these terms.
3) Usage of the Boolean OR to incorporate alternative spellings and synonyms.
4) Usage of the Boolean AND to link the major terms.

Required string is structured as under: ("Distributed software development" OR "Global software development") AND ("Risks "OR "Risk "OR" Challenges" OR "issues") AND ("Identification" OR "Assessment "OR" analyzing" OR "evaluating") AND ("Management "OR "Approaches" OR "Strategies"). The scope of this study is to find the complete list of studies which focused on risk assessment and management strategies in DSD. We searched well-known databases such as ACM digital library, IEEE Xplore, Science Direct, Springer and Google scholar. A complete list of searched and selected papers using the formulated search string is shown in TABLE 1.

TABLE 1. Searched result.

Databases	Total	Selected
IEEE Xplore	300	22
Google Scholar	422	38
ACM digital library	200	8
Science Direct	169	7
Springer	74	5

We further applied inclusion and exclusion criteria on identified studies;

1) INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria included:

1) Papers which are explicitly addressing our research questions.
2) Papers which are discussing risk management particular in distributed software development
3) Papers published from 2005 to 2016.

Exclusion criteria included:

1) Scope, context, and design of study are not clearly stated.
2) Content is repeated in similar papers.
3) Abstract or title does not explicitly address the risk management in DSD.

After exclusion and inclusion criteria, 80 studies have been selected from 1165 papers. For data extraction and analysis we thoroughly studied the selected papers to answer these four questions. The result of these selected studies is presented in following subsections.

B. DATA EXTRACTION AND ANALYSIS

In data extraction and analysis process, we have to answer the research question RQ1 to RQ4

RQ1: What are the existing approaches for risk assessment in Distributed Software development (DSD)?

Most failure of software could have been avoided if there were effective risk management practices from start of the development process. According to our selected studies, we identified several risk assessment approaches, which some of them are briefly described below.

A study is proposed, which considered important risk in offshore outsourcing, by using two panel Delphi study [15]. It was a three-round process to obtain results from different experts. The first round was the identification of risks by emailing questionnaire to selected participants (a total of 15 experts). They identified the most important risk that the project manager must have to pay attention to them. For assessment, one line description and limited line comments from experts were also included in the second round. The main reason was to check the consistency of different factors. A 10 point Likert scale was used to grade different factors to find relative importance between alternatives. Finally, round three was to validate the important factors.

In another study, a model was proposed for identifying risks before the start of the project [5]. Qualitative interviews and experience from the past projects were used to build a model. It consists of logical rules project characteristics and typical risks which can occur during Global Software Development (GSD). The identified set of rules described under which situation certain problem can occur. In total, 42 influencing factors and 140 rules were identified.

Keshlaf and Riddle [16] proposed a quantitative approach for risk assessment in Web and distributed (WD) projects. For assessment, it introduced a risk estimation equation called Total Risk Estimation Value (TREV) = Risk Exposure (RE) $*$ Web and Distributed Factor (WDF). A metric was designed for calculation of WDF $= \sum_{n=1}^{3} (colnotick * factorlevel)$. It considered three factors which can change the importance of risk priority. However, these factors are customizable and can be changed according to the situation.

Avritzer and Lima [17] used the empirical technique for assessment of scheduling risks in large distributed software projects. He observed two and half year projects data to identify factors which have an impact on productivity and team's ability to meet required schedule. His observation was that domain knowledge variability and team communication were important factors which should be taken into consideration to meet schedule. This approach can be useful for the practitioners at a very early stage before the actual software development begins.

Other risk assessment methods include Prikladnicki *et al.* [18] software development distribution model and well-defined steps for risk assessment in such a model. Khan *et al.*, [19] discussed and assessed requirement engineering risks in DSD. Magnusson [20] proposed a layered framework for outline risk and compliance management in GSD. Risks are assessed against each layer. Nurdiani *et al.*, [21] identified major risks and linked each risk item to its process relevance. Using this likelihood and impact of each risk is calculated. Similarly, project management and knowledge transfer related risk are assessed on the basis of literature in [22] and [23]. Similarly, questionnaire and literature review was also used in tandem for assessment of risks related to tools and project management in GSD [26], [27]. Risks associated with culture were prioritized by consulting different companies and already published results in the literature [28].

In 2014 Baloch *et al.*, coined the term snapshot to record risk rank and used this information to produce a relative ranking of alternatives [24]. Misra and Fernández-sanz [25] used SWOT analysis to analyze quality related risk in DSD. Another study proposed Analytical Network Process (ANP) approach to assess socio-technical risks in distributed development [8].

RQ2: What are the risk management strategies to overcome identified risks factors in Distributed Software Development (DSD)?

Risk management strategies include responses against each identified risks, which should be deserved, cost-effective and achievable. Four most common response strategies discussed in the literature are risk avoidance, risk transfer, risk mitigation and risk acceptance [9]–[11]. According to Pressman [29], most effective risk management strategies are proactive strategies. The project manager must establish proper plan to manage risks. The basic objective of proactive strategies is to avoid risks. However, it is difficult to avoid all risks. So there is a need to develop a proper plan, which enables it to respond to risks in an effective way. In reactive risks strategies, software project manager does nothing until something goes wrong.

A lot of studies have discussed control strategies for risks in DSD. The majority of these studies first identified risks, and then provides guidelines to control these risks. These guidelines are related to basic control strategies mentioned earlier. Silva *et al.*, [27] and Hawthorne and Perry [30] discussed control strategies to handle risks associated with project management in DSD. They suggested better planning and use of advanced techniques to minimize these risks especially schedule risks. Avritzer and Lima [17] also recommended using project management planning tool can reduce scheduling risks. Some studies provided guidelines to handle challenges related to the scrum or agile practices in GSD [31]–[33]. Another study [34] stated that, if using cloud it can facilitate project manager to handle DSD risks. Khan *et al.*, [36], identified some situational factors which help in requirement elicitation process.

Some studies proposed guidelines to control team related risks [28], [34], [35], and [37]. Deshpande *et al.* [28] stated that Hofstede model of culture is understood by organizations, it will help to remove frustration among different team members. Another study [37], described the importance of effective leadership for efficient communication to handle team related risks. A study [35] provided, suggestions to control issues related to temporal, geographical and socio cultural issues.

Knowledge sharing among different sites in DSD is also recommended as a control strategy for various risks. Wongthongtham *et al.,* [2] stated that knowledge sharing among remote team can solve problems associated with multisite DSD. Nidhra *et al.*, [23] discussed knowledge transfer issues and provided mitigation strategies for DSD. Similarly, Zahedi *et al.*, performed a literature review to find knowledge sharing challenges and practices. The authors proposed that knowledge sharing issues can be mitigated by using good communication media [4]. A review [39], which describes distributed agile development (DAD), stated that contract management is more important for agile projects. Fixed price projects are not suitable for agile.

RQ3: What are the factors (aspects and risk factors) that have an impact on decision-making during risk management in Distributed Software development (DSD)?

Previous sub sections depict that there is a need to consider such aspects which have an impact on both risk assessment and management strategies. Aspects are different characteristics or properties of the different organization. Identified aspects with some associated risks for risk assessment and basic management strategy described in**Table 2.**

The aspects identified from SLR were mapped to Leavitt organizational model [79] i.e. Task, Structure, Actors, and Technology. This model is successfully used to define software development risk of distinct areas [80]. Task covers productivity, documentation process, planning of workflow and development process etc. The structure includes a number of distributed sites, contextual factors for agile development, time zone, organizations and team structure etc. Actor consists of culture among sites, the relationship between offshore and vendor and personal attributes etc. Technology represents communication dependencies, interaction medium collaboration modes, and infrastructure. Against each aspect, impact on risk assessment and selection of suitable management strategy is described. This classification shows that selection of suitable management strategy against each aspect depends upon the result of risk assessment which includes possible risks and their exposure. Apart from the information shown in **Table 2**, risks against each aspect were also recorded. These identified risks are further prioritized to be used in the proposed DSS. This prioritization process is detailed in Section III.A.

RQ4: What kind of questions and rules can be used for decision making when assessing risks and selecting management strategies?

Question formulation, its description and a set of rules have been systematically identified and then described as shown in **Fig. 3** inspired from [13]. Questions and their description are extracted from the detailed analysis of selected SLR studies.

Question and rule formulation details are further explained in Section III.B. Complete questions and their respective answers are listed in Appendix A. Set of rules can be accessed and observed by using our tool (www.risksupports.com).

C. THREAT TO SLR VALIDITY

In this section, the potential threats to the validity of this study have been discussed. The four major categories of threats are (a) construct validity, (b) internal validity, (c)

TABLE 2. Aspects that impact on risk assessment and management strategy.

Dimension	Aspects	Impacts on risk assessment	Management strategies
	Culture among sites [5][19][7][6][21] [41][24][43][44] [32][33][28][36] [46][47][38][48] [48][23][49][39] [50][3][51]	Cultural differences among sites increase communication problem, lack of trust among sites, lack of project member interaction, inconsistent work practices and adversely affect the schedule.	Risk avoidance strategies should be chosen to overcome cultural differences among the sites. A proactive approach is best suited for this purpose.
	Trust [23][49][33] [44][50][23]	Problems occur due to lack of trust are knowledge management problem, reduction of motivation minimize coordination and also increase communication delay.	Risk avoidance, Risk mitigation, and risk transfer can be suitable strategy depending upon the situation
	Relationship between offshore and vendor [51]	Poor work, harsh contract, lack of access to client domain knowledge.	Risk mitigation and risk transfer are best suited management strategies to avoid some cost overrun.
	Personal attributes [23][52][48]	Increased number of projects, lack of interpersonal relationship and also some may affect upon schedule.	Risk avoidance strategy should be selected to handle these risks. Reactive risk management strategy is best suited to avoid large cost overrun
Actors	Internal-External interaction [52]	Time to the market and project continuity compliance problem.	Proactive, planning is required to overcome these sorts of challenges. Risk avoidance and risk mitigation and some sort of risk acceptance are best suited
	Staff size [5][7][20][22][23]	Lack of skill level can cause cost overrun problem, loss of tacit knowledge while team replacement.	Risk mitigation strategy is chosen to proper training about their technology and risk avoidance by a proper method of recruitment of staff.
	Experience developer[5][6] [23][51][53]	The inexperience of development can be a reason for productivity drop, lack of trust among the team and increased communication problem.	Risk mitigation, risk transfer or some sort like hire experience developer for training for their team. Proactive approach is best suited for this person
	Meeting practices [33]	Difficulties in meetings can reduce group awareness, or leads to collaboration difficulties	Risk avoidance or risk mitigation strategies should be chosen to overcome the difficulties by providing collaborative tools like wikis or instant messaging
	Team behavior [33] [40][54]	Improper attitude of team can be a reason for lack of trust, lack of team ness and lower the team spirit	Risk mitigation strategy. In the reactive strategy, there should be a small level of investment on this dimension. Proper project manager across sites can handle these issues.
	Team cognition [4]	Difficulties to identify knowledge to transfer, difficulties to mobilize and apply knowledge in other context and slowing of communication speed and pair programming	Reactive and risk mitigation strategy is best suited to handle these sort of challenges
	Motivation [35][15]	Poor quality of product, poor configuration management and the probability of artifact loss.	Risk mitigation, manager, and higher administration can take a step to overcome issues due to motivation.
	Customer availability [49][50] [15]	During distributed agile development unavailability of customer can cause inconsistencies to deal with requirement, inadequate quality assurance.	Risk mitigation and a proactive approach are used to mitigate risk associated with customer availability.
	Task allocation [6][1]	Task allocation in a non-transparent manner can be a quality issue, productivity decrease also impact on decrease in motivation.	Risk mitigation and risk transfer are best suited. Proactive risk management strategies are good to handle task allocation method.
	Domain knowledge [46]	Lack of domain knowledge will result in scope creep, high cost, poor services and misunderstanding about projects.	Risk avoidance, proactive approach is best suited. Proper planning and training session for team for their technologies and domain to avoid product failure.
	Vendor selection [3]	Poor infrastructure at vendor site, vendor is incompatible with client cause problem.	Proactive, risk avoidance and risk mitigation are best suited by seeing portfolio of vendor and observe domain knowledge.
	Project management [44][33][55][20] [22][53][12][54] [55][53][43][4] [59][1][22][15] [60][3]	Project delay due to late decision, loss of coordination, lack of conflict management, issues related to resource management.	Risk mitigation strategies are suited to handle the problem of management of projects. Proactive risk management strategies are best for this purpose.

TABLE 2. Aspects that impact on risk assessment and management strategy.

	Geographical distance [21][40][56][61] [26][30][31][34] [50][37][45][62] [47]	Lack of team cohesiveness, lack of trust, data loss during the transfer, fear of job, requirement understanding issues	Risk mitigation and risk transfer strategies are best for challenges to occur due to geographical distance. A proactive strategy is selected for this purpose because you have to plan ahead to avoid or manage the problem
	Temporal distance [21][23][56][40] [48][63][37][56] [12][31][32] [28][34][35][37] [44][64][59][48]	Lack of synchronous communication among sites, limited or non-overlapping working hour, integration problem and also it can decrease project effectiveness.	Risk avoidance and risk mitigation management strategies are selected for this purpose. Proactive approach is chosen because integration problem can be minimized by proper planning before it occurs
	Number of distributed sites [17][32][62]	Lack of security breach, lack of trust	Risk mitigation strategies should be chosen to handle these risks
	Contextual factors for agile [12]	These contextual factors have impacts on communication and collaboration which is a hurdle for agile practices in GSD.	Risk mitigation strategy is selected for this purpose. Risk acceptance and sometimes risk avoidance will be used depending upon condition.
Structure	Team Structure[46][41] [4] [37]	Misunderstanding among sites, improper recruitment can be the reason for the loss of opportunities for rich interaction and formal communication.	Risk transfer or risk mitigation strategy is best suited because this problem might fail overall project if not properly planned
	Organizations [31] [43] [36]	Different organization standard, inappropriate organization environment and organization politics.	Risk acceptance and risk mitigation are strategies which can be useful to handle organizational issues
	Social attributes [4]	No social activities will reason for the lack of trust among team member, lack of knowledge sharing, fear of job, lack of openness.	Risk acceptance and risk mitigation best suited to provide infrastructure for social interaction between different located team.
	Cloud based GSE [66]	Dependencies, unavailability of access to cloud, integration problem, technical debt and additional support cost	Risk avoidance and risk transfer or some sort of risk acceptance can be used to overcome the challenges associated with cloud based infrastructure
	Process maturity [5][16][21][67] [49][53][4][55]	Communication problems, decrease productivity, quality problems, insufficient process.	Proactive risk management strategy is best for this purpose. Risk mitigation and risk transfer can be used to overcome problems due to process maturity. There should be proper plan ahead to overcome these challenges.
	Knowledge management system [2][17][16] [68][69][58][12] [70][67][34][65] [48][19][40][23]	Difficulties in cooperation among teams, reason for lack of domain knowledge, decrease in productivity and also in ability of knowledge transfer makes difficulties to reach upon a common method	Risk avoidance by a proper electronic guide for knowledge management. A proactive approach is good to avoid challenges occurred due to knowledge management
	Complexity [5] [18] [5] [16]	Complexity of project will decrease work force motivation or leads to incompatible data formats and strategic and tactical issues	Risk mitigation strategy is selected to overcome the challenges of complexity
	Awareness of work [2] [66] [63] [38] [1]	Lack of awareness of work can cause communication problem, misinterpretation over issues	Risk management strategy is selected to overcome the challenges of complexity
	Productivity [5] [17] [6] [62] [38]	Productivity will decrease when there is a lack of domain knowledge and little experience.	Risk avoidance and risk mitigation strategies can be chosen to handle the problems associated with productivity.
Task	Documentation process [18] [23] [54] [38]	Lack of documentation can cause problems in team collaboration, knowledge transfer challenges, risk management problems and lack of documentation can cause problems in requirement specification	Risk mitigation or risk avoidance strategies are suitable to handle problems related to the documentation process.

TABLE 2. Aspects that impact on risk assessment and management strategy.

Development process [12] [44] [3]	The poor development process will lead to poor product functionalities, difficulties to understand remote teams about their task, dispersed decision making is difficult.	Risk avoidance proactive strategies are best suited to handle development process risk, you have to plan ahead to avoid or manage the problem.
Software quality [20] [6] [67] [54] [25][42] [22]	Difficulties to control quality when there is lot of different locations	Risk acceptance level should be defined associated with quality. Risk mitigation strategies with proactive approach is suitable to mitigate issues of quality
Project delivery or project performance [55][45]	Project delivery will postpone due to unavailability of the key resource. Project performance can also be influenced by project sponsor involvement	Risk avoidance or risk mitigation strategies are best suited to handle the problem related to project delivery or project performance
Component base development [2][54]	Output of one component can be misinterpreted by another input component, distance can cause issues that output from one team is misunderstood by another team	Risk transfer or risk mitigation strategies will be good option to handle issues related to component base development, some sort of risk acceptance can also be suitable where you have large cost overrun
Requirement practices [23] [64] [47] [51] [69] [41] [61] [38] [3] [70] [40] [41] [71] [43]	Inappropriate requirement engineering practices can cause issues, inaccurate modeling. Refining and translation of requirement at different level is challenging	Risk avoidance or risk acceptance and sometimes risk mitigation is suitable for the challenges associated with requirement practices
Coding standard[54]	Difference in coding standard causing problem of integration of component	Risk avoidance and risk transfer are better suited for this purpose. Proactive management strategies are better suited for this purpose
Design and modeling [39] [3]	Inconsistency in design standard cause problems of code integration, traceability issues are due to style variation.	Risk mitigation and risk acceptance both can be used depends on the scenario.
Architecture [59] [3]	Lack of strong skilled architecture role may totally disturb project, integration failure is due to architectural dependencies	Risk avoidance and risk tolerance are better suited to handle problem associated with architecture, Proactive risk management strategies are required because the problem in architecture have a ripple effect to the overall product.
Configuration management [3]	Configuration management problems are group awareness, problems caused by the distributed developers include dependency, delay, and increased time to complete maintenance.	Risk mitigation with proper planning can be used to overcome challenges due to configuration, management
Software Development Life Cycle [1]	Poor technical debt management, ineffective stand up meetings, issues of pair programming while agile development	Risk avoidance, risk transfer, and risk mitigation can be used depending upon the phase of development.
Communication dependencies [5] [2] [7] [6] [19] [33] [54] [6] [21] [75] [74] [40] [23] [67] [49] [24] [76] [68] [57] [54] [63] [37] [72] [12] [42] [70] [45] [3]	Ineffective communication dependencies can cause management problem, poor development requirement confusion etc.	Risk mitigation strategies are best suited for this purpose. The Proper tool of communication and knowledge management system can help to minimize these problems. Proactive risk management strategy is best for this type of problem.
Interaction medium [19] [40] [37] [41] [12] [48]	Interaction medium have impact on development speed, lack of awareness of member identity.	Risk mitigation or risk transfer strategy can be selected to overcome the problem occurred due to interaction medium.
Collaboration modes [34] [18] [40] [78] [3] [1] [48]	Collaboration modes can cause communication problems, lack of group awareness and tension between team etc.	Risk avoidance and risk mitigation strategies are best suited to handle risk associated with collaboration mode.

TABLE 2. Aspects that impact on risk assessment and management strategy.

Technology	Internet medium [42]	Internet communication and unavailability of internet connection cause schedule overrun.	Risk avoidance and risk mitigation strategy is selected to overcome this problem.
	People –technology [52]	Fear of multi technologies, multi development platforms with different standard.	Risk mitigation and reactive strategies are best suited for providing training to the practitioner. It will reduce the probability of this type of problem.
	Technology –technology [52] [15] [1][48]	Misalignment of IT strategies among distributed teams, problem in integration of multi technology platform.	Risk avoidance and risk transfer can be better suited to handle these problems.
	Infrastructure [64] [63] [31] [42]	Infrastructure can cause lack of adequate facilities, lack of knowledge management and transfer among the team. Not a proper infrastructure can result in tool mismatch, unreliable telecommunication infrastructure.	The risk avoidance proactive risk management strategy is suitable because there should be proper planning to overcome these issues.
	Tool [26] [35] [4]	Conflicts due to tools are an inappropriate use of synchronous and asynchronous communication, difficulties to adapt and learn the tool. Difference in tool cause lack of data integration problems	Risk avoidance using proactive approach is best suited to handle conflict arises due to tools.
	Security system [71][51][61][5] [15]	Issues related to security system are confidentiality and privacy.	Risk avoidance and risk mitigation both are suitable according to the condition. Proactive approach is best suited

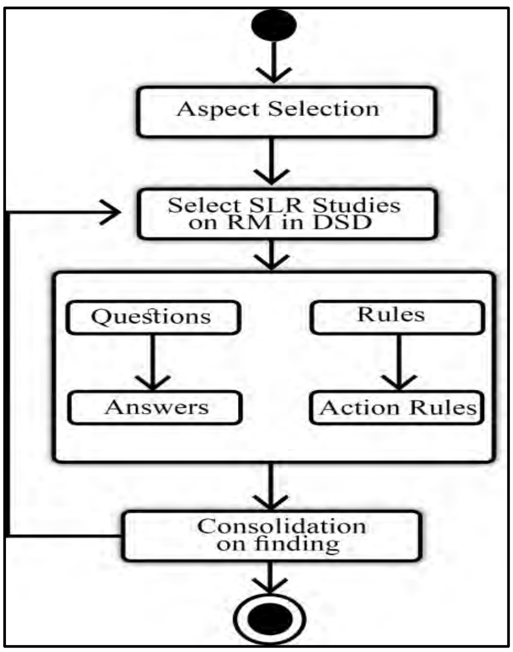


FIGURE 3. Activites involved in extraction of findings.

conclusion validity, and (d) external validity as described by Tüzün *et al.*, [13].

1) CONSTRUCT VALIDITY

Construct validity shows to which extent SLR represents the aim of researchers and the way it is measured with respect to research questions. Different tactics were applied to overcome the threats to construct validity. A threat to the exclusion of the relevant study was minimized by a well-established SLR protocol, based on a well-defined searching strategy. In the search process, any study that does not mention the words "risk", "challenges", or treats" in the title, abstract or keywords of the article have been excluded from the set of primary studies. An inclusion/exclusion criterion was applied to screen primary studies. After the selection of primary study, three main questions were addressed to ensure the validity of study selection outcome. These questions are explained below:

- Completeness: whether all the aspects and rules were successfully extracted from the literature or not?
- Correctness: Do we have valid aspect and rule pairs?
- Non-redundancy: Are all the aspects and rules necessary?

To deal with these questions, a data model, based on different models, was applied. A data extraction process was checked through this model, by considering randomly selected set of studies. All of the studies were analyzed with respect to aspects, rules questions, and answers. The analysis reveals that some papers lacked in the requirements for extracting the data. To overcome biases, the results of selected studies, where all data elements were mentioned, have been considered. All the identified terms were checked for their meanings by analyzing different terms of explanation.

2) INTERNAL VALIDITY

In this type of validity, threats are raised due to an invalid causal relationship based on the findings. In the context of this study, all aspects and rules for risk assessment decision were determined. Therefore, it was assured that the relevance of the study was fulfilled. The priority and weight concept of derived aspects were also considered. To weigh these aspects, numbers of citations of each study were considered; the publication source and survey based on different ideas were checked. All the aspects with their references have been enlisted in the table.

3) CONCLUSION VALIDITY

In conclusion validity, threats to the reliability of this research are addressed. Threats related to study selection and data extraction process was mitigated by adopting a well-defined SLR protocol based on a well-established searching process. For this purpose, study selection and data extraction processes were performed by three researchers. Consequently, the use of well-established systematic literature review and involvement of these researchers minimize threats to conclusion validity.

4) EXTERNAL VALIDITY

External validity refers to generalization of the findings derived from the primary studies. In the context of this research, primary studies and extracted data elements have been generalized to meet the overall goal of review. Hence, a careful review protocol was applied and wide scope of the relevant study was discussed.

III. PROPOSED DECISION SUPPORT SYSTEM (DSS)

Tools help in decision making for risk assessment and selection of suitable management strategy. A decision support system is developed by taking into consideration the earlier defined DSM and output of SLR. The decision-making process involves a number of steps, including a set of questions, answers and triggering rules. It is a web-based tool that is freely available for organizations. It is developed using MVC.Net framework using Entity Framework with SQL server. For the client-side J query and Java script are used. This tool is developed for both decision makers and decision designers. Decision designers can use and configure the tool for the decision-making process. The project manager or the person who is responsible for decision making can select and use defined decision support systems, which will support them for risk assessment and selection of management strategy.

As shown in Fig. 4, DSS for risk assessment and management strategy consists of three components: Knowledge Base (KB), Decision Support Engine (DSE) and Graphical User Interface (GUI). The KB of DSS and DSE both represent database and decision support aspects, respectively. Knowledge base repository includes the output of the SLR. It includes four common dimensions, 49 aspects with their corresponding 524 risks, their prioritization and respective management strategies. The DSE is used for reasoning according to the rules derived from the SLR or any more information provided by the decision maker. The GUI allows the user to interact with the KBDSS for risk management

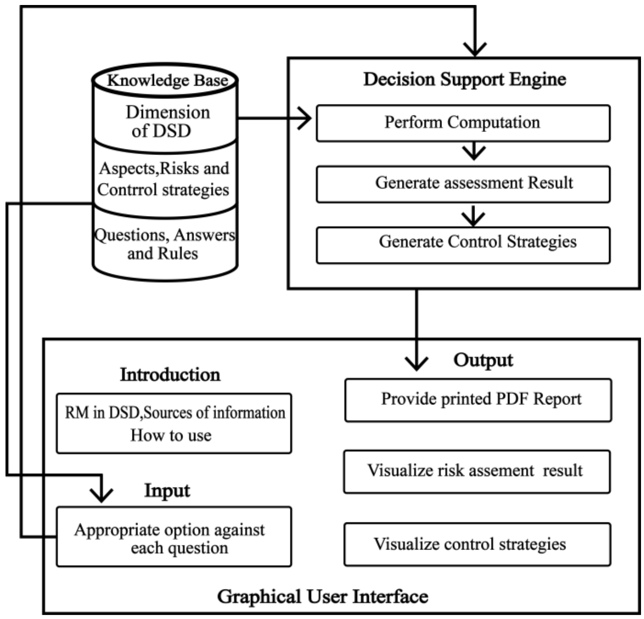


FIGURE 4. Architecture of DSS.

in DSD. It also provides basic information about the system and the way it can be used. The GUI will present report and visualization results in the form of radar charts and bar charts.

A. PRIORITIZATION OF IDENTIFIED RISKS AGAINST EACH ASPECT

Previous sections described the most probable risks and available safeguards in DSD. After identification of specific threats, next step is to consistently prioritize previously identified risks. Prioritization will assist the decision maker to find a relative ranking of alternatives. It also helps him or the project manager in project planning and assigning resources to different activities of the project. A common Analytical Hierarchical Process (AHP) method, proposed by Saaty [81], is used to find out the relative ranking of different risks factors.

AHP is used to find the best alternative from a list of alternatives and then rank them to get a prioritized list of factors. It has been successfully used in many distinct fields, such as evaluation of agricultural water management [82], risk assessment of Nano Carbon material [83], prioritizing hazards in large manufacturing company [84], selecting safety measures to reduce mechanical hazards of industrial machinery [85] and, determining and prioritizing list of quality attributes from stakeholder [86], etc.

In this paper, the AHP method is used to rank risk factors, associated with DSD, to avoid failure. AHP is applied in the same way as proposed by Saaty [81]. It is briefly described below.

Step 1: Identify and define the factors that are used to be evaluated or ranked according to their alternatives. In this case, risk factors associated with each identified aspect are considered, as shown in **Table 2**.

*Step 2:*Pairwise compare factors, which will be used to find the relative importance of different factors. Output of this

TABLE 3. Linguistic scale.

Relative ranking	Linguistic scale
1	Just equal
3	Moderate dominance
5	Strong dominance
7	Very strong dominance
9	Absolute dominance
2,4,6,8	Intermediate values

phase is an m x m matrix, M ($m_{i,j}$) where i, j = 1 ,2,3…n.

$$M = \begin{bmatrix} m_{11} & m_{12....} & m_{1n} \\ m_{21} & m_{22....} & m_{2n} \\ . & . & . \\ . & . & . \\ . & . & . \\ m_{m1} & m_{m2....} & m_{mn} \end{bmatrix} \text{ where } mi,$$

$$j > 0 \text{ and } mi, j = 1/(mi, j) \tag{1}$$

Two factors have similar relative importance when both i and j are equal, i.e. $m_{i,j=}m_{i,j}. = 1$.

TABLE 3 shows the relative ranking of $m_{i,j}$ with respect to linguistic scale.

Step 3: Compute the resultant weight on the basis of pair-wise comparison matrix, M. After calculation, normalize the obtained weights.

$$W = (w'1, w'2, w'3, \ldots w'n)^T \tag{2}$$

The weight of each matrix is calculated by dividing indexes of the matrix with the sum of that column values. After calculation, add all values and then divide it by the number of elements in that row.

$$w'i = \sum_{j=0} \left(\frac{m_{ij}}{\sum_i m_{ij}} \right) \tag{3}$$

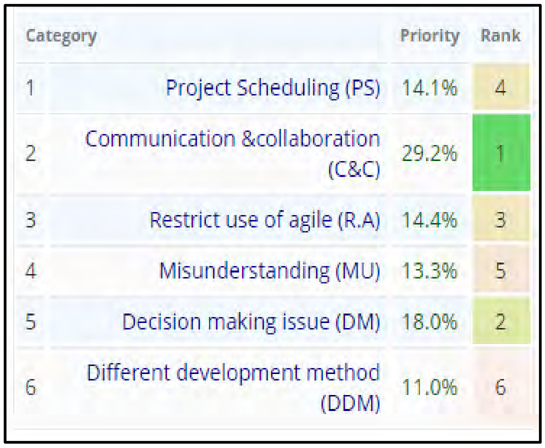
Consistency index to check consistency of pair wise comparison is computed as

$$CI = \frac{\lambda max - n}{n - 1} \tag{4}$$

λmax is the maximum value of the Eigen value. It is calculated according to the **equation 5** given below.

$$\lambda max = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw')_i}{w'i} \tag{5}$$

Pairwise comparison matrix, M, is used to obtain objective priorities of different factors. Pairwise comparison of a general matrix of an aspect number of sites is given below (**TABLE 4**; meaning of acronyms are given in Fig. 5). To calculate the resultant weight of each factor and consistency index using the online tool [87], this will calculate the relative priorities of each risk factor, as shown in **Fig. 5**. Matrix M is calculated with the help of the SLR findings. Repetition of factors in different studies and consultation with industrial experts and users were used to find the priority of different factors according to the linguistic scale. However, no structural questionnaire was used to obtain priority from experts.



Category		Priority	Rank
1	Project Scheduling (PS)	14.1%	4
2	Communication &collaboration (C&C)	29.2%	1
3	Restrict use of agile (R.A)	14.4%	3
4	Misunderstanding (MU)	13.3%	5
5	Decision making issue (DM)	18.0%	2
6	Different development method (DDM)	11.0%	6

FIGURE 5. Risk priority for number of sites.

TABLE 4. AHP matrix.

	PS	C&C	R.A	M	DM	D.D
PS	1	1/3	2	2	¼	1
C&C	3	1	2	2	2	3
R.A	½	½	1	1	2	1
M	½	½	1	1	3	4
DM	4	½	½	1/3	1	2
DD	1	1/3	1	¼	½	1

B. RULES AND QUESTION FORMULATION

Questions are metrics, which are used to measure the impact of each aspect of risk management. Some aspects are measured with the help of more than one question, which has a huge impact on decision making. The guidelines proposed by Kitchenham and Pfleeger [88] are followed to prove the internal consistency and reliability of questions and their answers.

A case study of Philips [89] was selected from the literature that focuses on GSD. Different expert users analyzed the case study to answer the questions with respect to the context of the company. This exercise helped to check internal consistency and reliability of questions and answers with the help of Cronbach Alpha test. The purpose of this process was to remove ambiguities from the questionnaire, formed to motivate the respondents for answering the questions.

Next process involves the identification and description of rules. Rules are the identified risks, assessment results, and their control strategies. They are extracted according to their related questions. Action rules are based upon the answers to each question. Both the rules and action rules are identified from the selected SLR studies. Identified questions, answers, rules and action rules are discussed and consolidated, which led to the final result. For any inconsistency or ambiguity in results, selected SLR studies were analyzed again for the final decision. Finally, all identified artifacts were categorized and placed into Leavitt organizational model. The question template is shown in **Table 5**.

It includes question identifier, its description, Leavitt dimension, aspect and possible answers. Every question has

TABLE 5. Question template.

Element	Explanation
ID	ID distinguishes different questions.
Aspects	Aspects identified which will be assessed using question.
Dimension	Possible Leavitt dimension where the aspect fall.
Question	Question describes what to elicit information.
Description	Short description about question.
Answers	Possible answer with description.

TABLE 6. An example of the question template.

Q.ID	8
Aspects	Number of distributed sites.
Dimension	Structure.
Question	How many sites are involved during DSD?
Description	Number of sites, the distance involved during DSD.
Answers	High (Include more than 10 sites both offsite and offshore) Low (Include 5 to 10 sites) Medium (Include 1 to 5 sites in distributed location)

TABLE 7. Rule example.

Related Question	What is the process maturity across sites?
Answer	Medium (different maturity level across sites)
Risks	Lack of uniform processes among different development sites is serious issues across different sites. This will result in communication problem, coordination problem and it directly affects the quality of software product, cost and project delivery time.
Control strategy	Risk acceptance and risk tolerance: Professional accreditation of distributed teams which might increase trust among people. Train all project managers. Using CMMI and certifying professional.

two or more answers. **TABLE 6** is an example of the question template as also discussed by [13]. Complete questions and their respective answers are listed in Appendix A. A Set of rules can be accessed and observed by using the tool (www.risksupports.com). In the system, answers against each question help in delivering a decision. Decisions are based upon the rules defined by the system. An example of rule is depicted in **TABLE 7**. All questions, answers, and rules are identified and extracted after detailed analysis of SLR studies.

The general template for rule in DSS is IF (condition), performOperation(); provideFeedback(). The condition represents aspect value, which will be assessed by the questions. Perform operation will take some action according to rules and then provide feedback to the user.

C. DSS CONFIGURATION

A knowledge base has to be configured before using the DSS system. **Fig. 6** is a whole depiction of the workflow. The basic constructs of the system are project dimensions, aspects, risks against every aspect and management strategies. This system can be customized by a decision maker depending upon the conditions and his preferences. For describing a new term, its name and description are essential.

This is followed by the configuring of the questions, which can be used for the assessment of risks in DSD and selection of management strategy. As discussed earlier, questions can be of two types, i.e. general questions and questions with multiple options, which are being used for risk assessment. The set of rules, whose focus on the impact of input, was provided by the decision maker. It mainly answers the given questions and also suggestions provided by the system. Every rule is connected to both risk assessment and selection of management strategy.

After configuration of all questions, answers and their corresponding rules, a report is generated. Report template includes general information of the decision maker and his organization, results of the assessment, best suitable strategies and its description in DSD. Each question is selected or rejected based on the choice of the decision maker. Therefore, a report is a complete picture of an overall assessment of risks and provides suggestions for selection of management strategy in DSD. Some part of the report is same for every assessment; however, a portion of the report is changed depending upon the information and answers provided by the decision maker. The report is generated upon user's request in textual form. Results are visualized in the form of radar chart and bar chart to aid decision maker during the assessment.

D. USAGE OF SYSTEM

After configuration of the knowledge base, the system is ready for decision-making process to assess risks in DSD and select suitable management strategy. The sequence diagram shows whole workflow of the system in **Fig. 6**. A component named as the scheduler is responsible for the selection of question from the knowledge base and retrieving answers from the user. **Fig. 7** is a representation of questions that have to be answered inspired from [13].

Answers trigged by the decision maker are also stored in the database. Rules are retrieved from the knowledge base to take an action against the response provided by the decision maker for questions. A report is generated, providing detailed information and recommendations on risk assessment and management strategies. Visual representation of risk assessment is done by using radar chart and bar charts for control strategy against each aspect. The output of DSS against the results of selected case studies along with the visualization is shown in next sections.

IV. EVALUATION

A. CASE STUDY DESIGN

In this section, the design of the selection of case studies is discussed, which is used for validation of the proposed system. Guidelines, proposed by Runeson and Höst [90], are followed for conducting case study research in software engineering. This process includes a selection of appropriate case studies and finding related data.

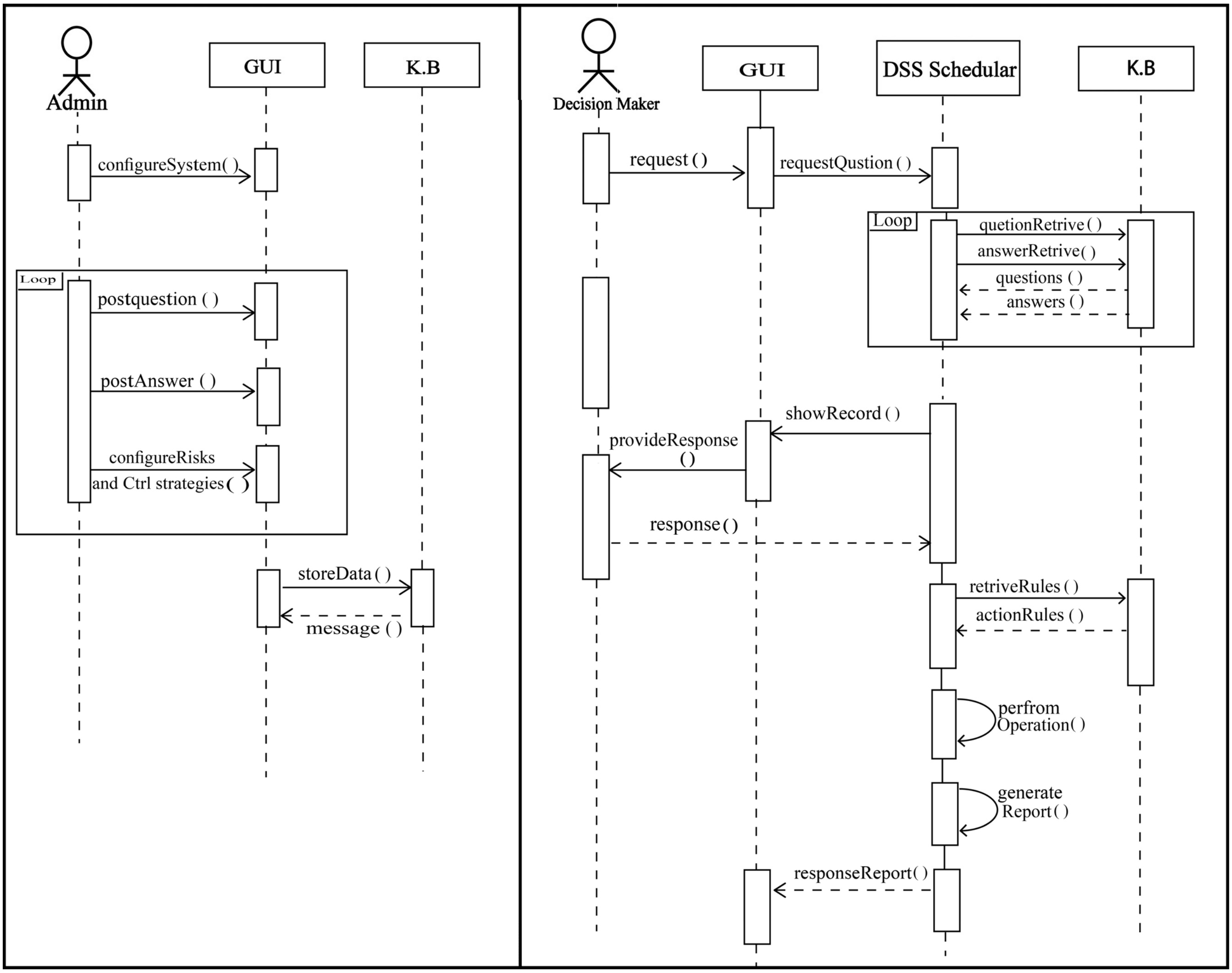


FIGURE 6. **Sequence diagram of work flow in DSS.**

B. SELECTED CASE STUDY

Research triangulation is an important part of the case study. It helps to increase the precision of empirical research [90]. The term triangulation means taking different angles towards the studied object. The research includes two different types of cases – retrospective analysis and prospective analysis for assessment of risks in DSD inspired from Tüzün *et al.,* [13]. In a retrospective analysis, case studies published in the literature are analyzed; whereas prospective analysis discusses the qualitative analysis of the data from the company Enabling System. Three different types of triangulations are applied [90], that is Data triangulation (multiple case studies), Observer triangulation (multiple observers), and Methodological triangulation (direct and indirect data extraction from the literature as well as an industrial case study). Finally, two case studies are obtained from literature and one from the industry for the precision of validation.

Case studies from literature have been selected upon the basis of 'most citation' in the domain of globally distributed development, which resulted in the selection of Philips [89] and Siemens [91] experience in this area. Selections of these case studies were due to the availability of a lot of information in already published studies. These studies helped us to mine answers for the questions, which were discussed earlier.

Philips consumer electronics is one of the largest electronic companies in the world. Its annual turnover is about €10 billion. The Software development of Philips is carried out over 10 different sites in the world – 73% in Asia and 23% in Europe [89]. The second company, Siemens, is a globally operating company and has about 30,000 software engineers worldwide [92]. They are experienced in distributed and different nature of software projects, including embedded systems, case management, and medical applications etc. [91]. Another case study of a company, Enabling System, has been obtained from the industry, where direct data is collected in order to validate DSS. Enabling System is a global software company that provides services and solutions for app development, embedded systems, customized and location based

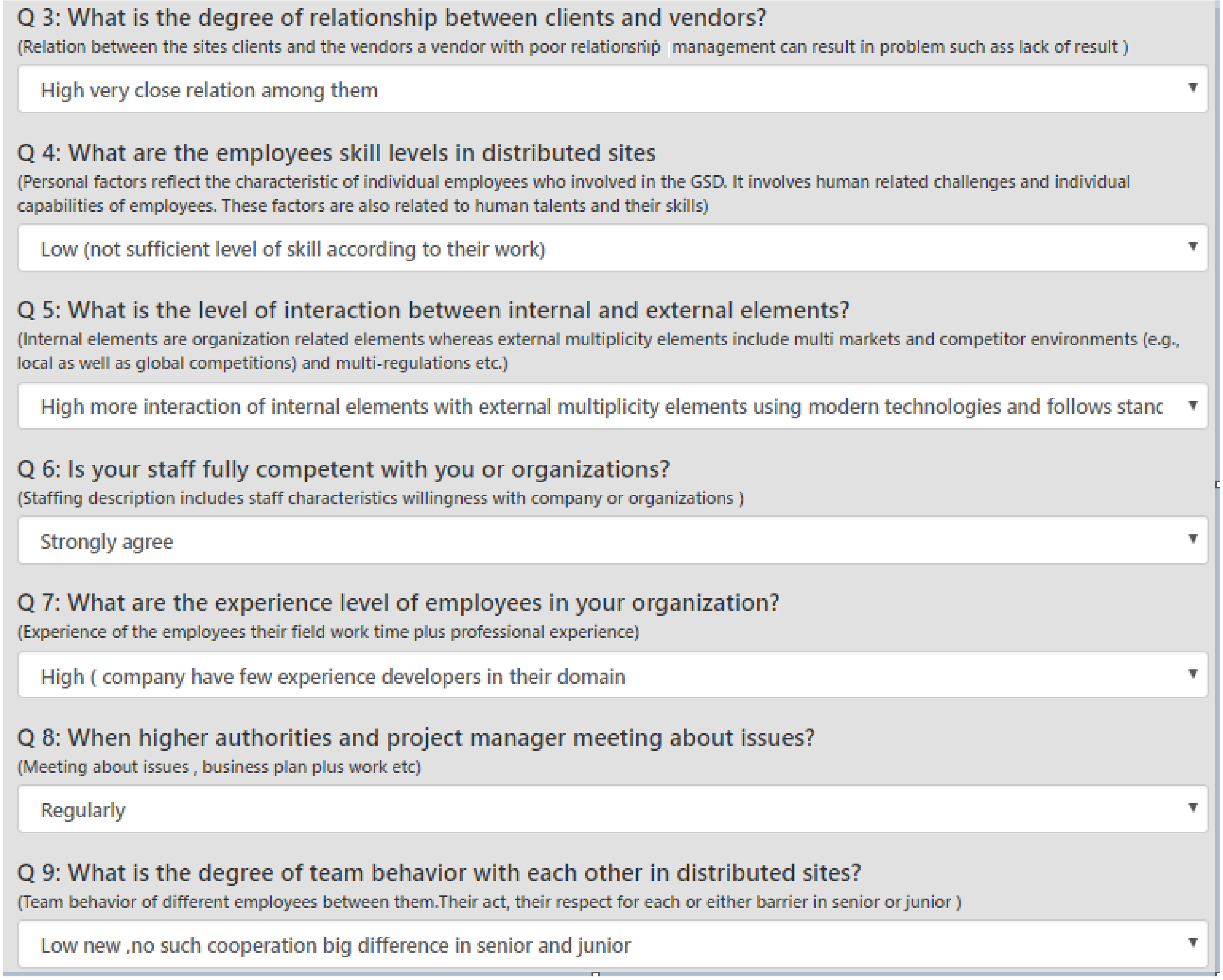


FIGURE 7. Questions to be answered.

services. Its headquarter is in California; whereas its offices are in Silicon Valley and Pakistan [93]. The aim of this case study was to measure the impact of DSS in real industrial context.

TABLE 8 shows the protocol of whole case study. Retrospective case studies were used to compare assessment of risks and selection of control strategies provided by DSS with published results. A prospective study is to measure differences before and after the use of DSS. The impact of DSS is measured by asking a set of questions before and after the use of the tool. Data collection and analysis of these case studies are different and both of them are separately defined.

1) RETROSPECTIVE CASE STUDIES

The data against the questionnaire are indirectly collected after deep analysis of selected case studies. Relevant papers that cited the case study are also considered in order to get appropriate answers. Data collection and analysis are defined hereunder.

- *Collection of all papers related to the case study*: This was an easy task that involved taking in all cited papers of the case study.
- *Feeding answers to questions into DSS*: Answers are mined from related papers. Possibilities of answers are either explicitly written or mined from the knowledge source.
- *Feeding results into DSS*: Results are acquired by discussing over the ambiguities in answers derived from the knowledge source. They are fed into DSS.
- *Analyzing results*: Finally, results of DSS are analyzed for risk assessment and control strategies. They are compared with knowledge sources and analyzed.

2) PROSPECTIVE CASE STUDY

The data are directly collected by interviewing the Chief Technical Officer of the company, Enabling System. The Chief Technical Officer has six years of experience in distributed development. The company has around three

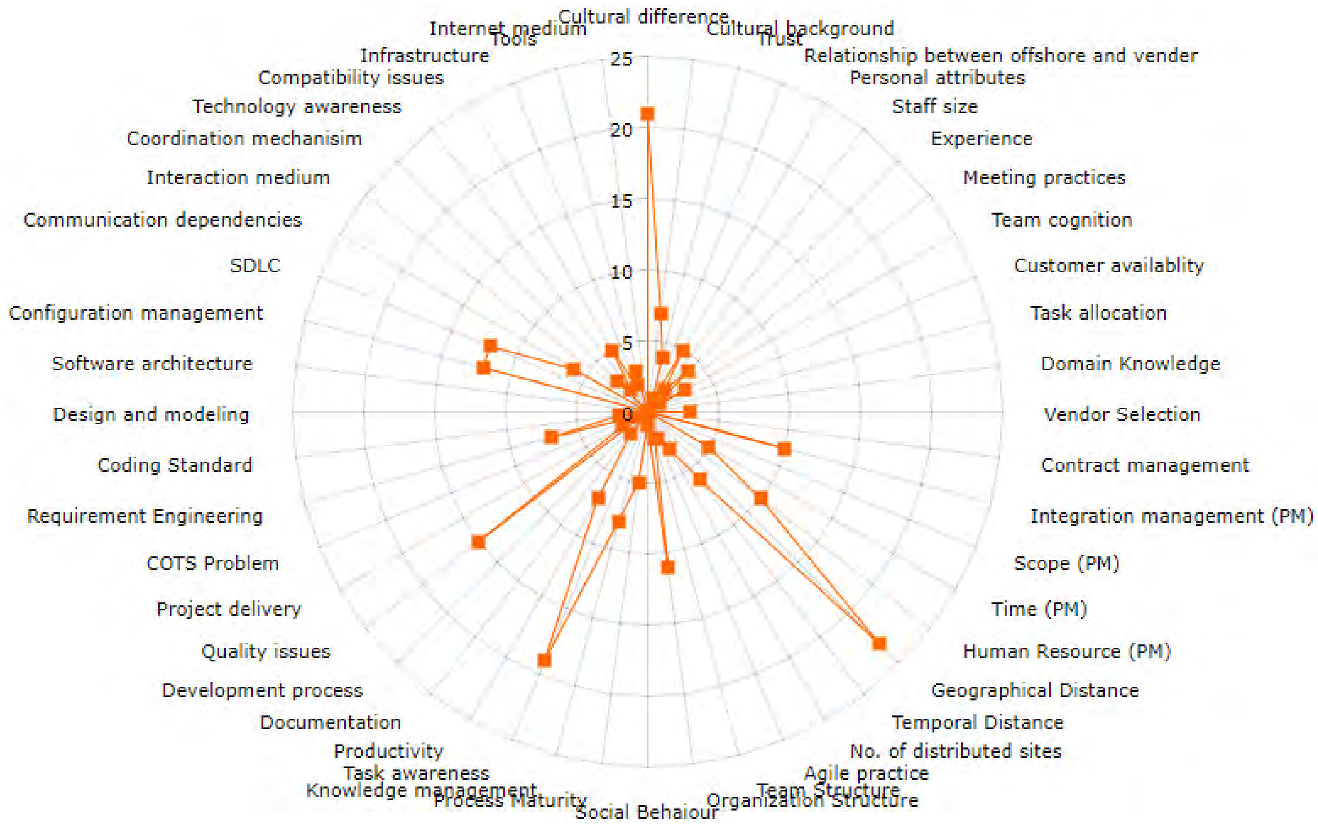


FIGURE 8. Radar chart for Philips case study.

TABLE 8. Case study design.

Case Study design	Retrospective analysis		Prospective analysis
	Philips experience	Siemens experience	
Aim	Analysis of risk assessment and control strategies results provided by DSS with published result.		Assessment of the practical use of DSS.
Questions	Q1: How much decision about risk assessment provided by DSS is aligned with the decision of case study? Q2: How much decision about selection of control strategies is aligned with the decision of case study?		Q1: How much DSS support decision making in risk assessment in DSD? Q2: How much DSS support decision making for selection of control strategies? Q3: How practical is the DSS for decision making in risks management in DSD.
Sources	Case study and studies cited these case studies.		Project manager Practitioner
Data collection	Indirect data collection (Document analysis and discussion).		Direct data collection (Interview with structured and unstructured questions)
Data analysis	Qualitative analysis (using radar chart and tabulated result).		Qualitative analysis (using radar chart and tabulated result).

years of experience but is not using any standard risk management methodology to handle uncertainties. Semi structured, predefined set of questions were asked in order to assess their observation on DSS tool.

- *Meeting with the decision maker*: meeting with decision maker of the company was scheduled, the purpose of which is to gain insight into risk management practices followed by the company.
- *DSS tool demonstration*: the DSS tool was demonstrated to elaborate on its purpose, operation and some detail on its outcome/results.
- *Using the DSS tool*: the tool was used by the decision maker, who in this case was Chief Technical Officer, without the assistance of researcher. It helped in answering each question independently and unbiased.
- *Result analysis*: results in the forms, visualization, and report, were analyzed.

- *Post-interview*: the post-interview session was conducted to identify the impact of DSS tool on decision making during risk management.
- *Discussion*: Finally initial interview, post interview and results of DSS are discussed with the decision maker to analyze the impact of DSS.

C. CASE STUDIES EVALUATION

This section discusses the results of the aforementioned retrospective and prospective case studies. Threats to validity for results have also been stated.

1) RETROSPECTIVE CASE STUDY

The results of case studies are presented in three formats: (1) radar chart, which represents risks assessment for a company in DSD, (2) the table represents control strategy against each identified risk, (3) general discussion regarding the case study. The result of case studies, Philips and Siemens experience in DSD is discussed separately. The answer to each question is mined from published cited paper or from case study directly.

Radar chart for assessment of risks in DSD after execution of case study Philips is shown in **Fig. 8**. The system provides the overall result of all dimensions, and then radar charts for each dimension can be separately depicted. Results are given for the answers that are mined from the cited paper or a case study directly. They show a number of risks along with the prioritized list of risks associated with each aspect. Prioritization of risks can be seen by hovering mouse over each aspect. Most of the answers are reply-inward. This means that a limited number of risks are associated with Philips during DSD.

The result of the control strategy is shown in TABLE 9 First two columns show the question ID and the question itself, respectively. The third column depicts answers to questions and citations of papers from where the answer is mined. The fourth column represents dimensions of each question and the last column represents control strategy against risks with respect to mined answers and the associated rule. The cell with red symbol shows that risks should be avoided, pink color depicts that risk should be mitigated, whereas blue and green represent tolerance and acceptance of risks, respectively. In Philips case, most of the answers have red and pink colors, which mean that risks associated with these aspects should be avoided or mitigated.

Radar chart for Siemens is shown in TABLE 10. The justification for risk assessment can be derived from the radar chart. Some similar results are observed in Philips and Siemens case studies. For control strategies, Siemens provides fifteen risk acceptance control strategies as shown in **Fig. 11** and Philips results depicts nineteen risk acceptance strategies. Philips had more mature task-related activities than Siemens. This shows that Siemens need to improve some of its areas. Given below are the questions against which evaluation is performed.

TABLE 9. Threat to validity of case studies.

Case study	Threat	Measure against threat
Retrospective case study (Literature)	Incorrect answers can be mined regarding both for risk assessment and selection of control strategies in corresponding case study literature	A detailed protocol is discussed in **Table 8.**
Prospective case study (Industrial)	Wrong interpretation regarding questions by decision maker	To make sure the uniqueness of questions detailed description is added against questions are added. Guidelines proposed by Kitchenham.*et.al*, [91] are followed to ensure the validity of questionnaire.
	Wrong interpretation regarding answers by interviewed persons	Detail description is added to each option. Several pilot runs to ensure that options provided against each question are clear and concise. The population included into the pilot run is engineers, researcher, and persons who have several years of experience in DSD.
	Wrong interpretation regarding against open questions by the decision maker	To ensure this validity, questions are verified by interviewed persons.

TABLE 10. Comparative analysis with existing studies.

Ref.	Aspects	Total Risks	Control Strategy	Rules
[3]	8	85 Generic risks	✓	×
[22]	10	18 Project management risks	×	×
[19]	24	79 Requirement Engineering risks	×	×
[5]	×	72 Generic risks	×	36
[51]	8	24 development risks	✓	×
Proposed DSS	**49**	**524 Generic risks**	✓	**163**

Q1: How much decision about risk assessment, provided by DSS, is aligned with the decision of the case study?

Analyses of results of both case studies are similar, as elaborated in Philips and Siemens publication. Since both of these are well-known experience reports on DSD, the DSS tool is not only providing decisions for risk assessment but also provides a rationale for each risk described in the literature. For example, in Siemens case study, it is observed that domain knowledge is not sufficient. DSS provides a number of risks and a prioritized list of risks. Another work [6] that cites this case study states that Siemens have insufficient abilities

Q.ID	Question	Answers	Dimension	Avoidance	Mitigation	Transfer	Acceptance
1	What can be the cultural difference between distributed sites ?	High section 4.1 [92]	Actors				
2	What is the cultural background of different distributed sites ?	Same organization section 5.0 [92], [97]	Actors				
3	What is trust level among employees in distributed sites	Medium	Actors				
4	What is the degree of relationship between clients and vendors?	High section 4.1 [92]	Actors				
5	What are the employees skill levels in distributed sites	Medium section 4.3 [92]	Actors				
6	Is your staff fully competent with you or organizations?	Agree section 4.3 [92]	Actors				
7	What are the experience level of employees in your organization?	Medium	Actors				
8	When higher authorities and project manager meeting about issues?	Regularly	Actors				
9	What is the team cognition level between distributed team?	High section 4.1 [92]	Actors				
10	How much customer available during development process?	High section 3.0 [92]	Actors				
11	Is task divided into sub task allocated, and then allocated to distributed sites ?	Agree section 4.1 [92],[98]	Actors				
12	What is the degree of domain knowledge on particular site?	Low section 1.1 [92]	Actors				
13	Is vendor is capable for developing required product?	Medium section 5.0 [92]	Actors				
14	Is contract between sites or parties are concise and clear?	partially agree section 3.0 [92]	Actors				

FIGURE 9. Tabulated control strategies of Philips.

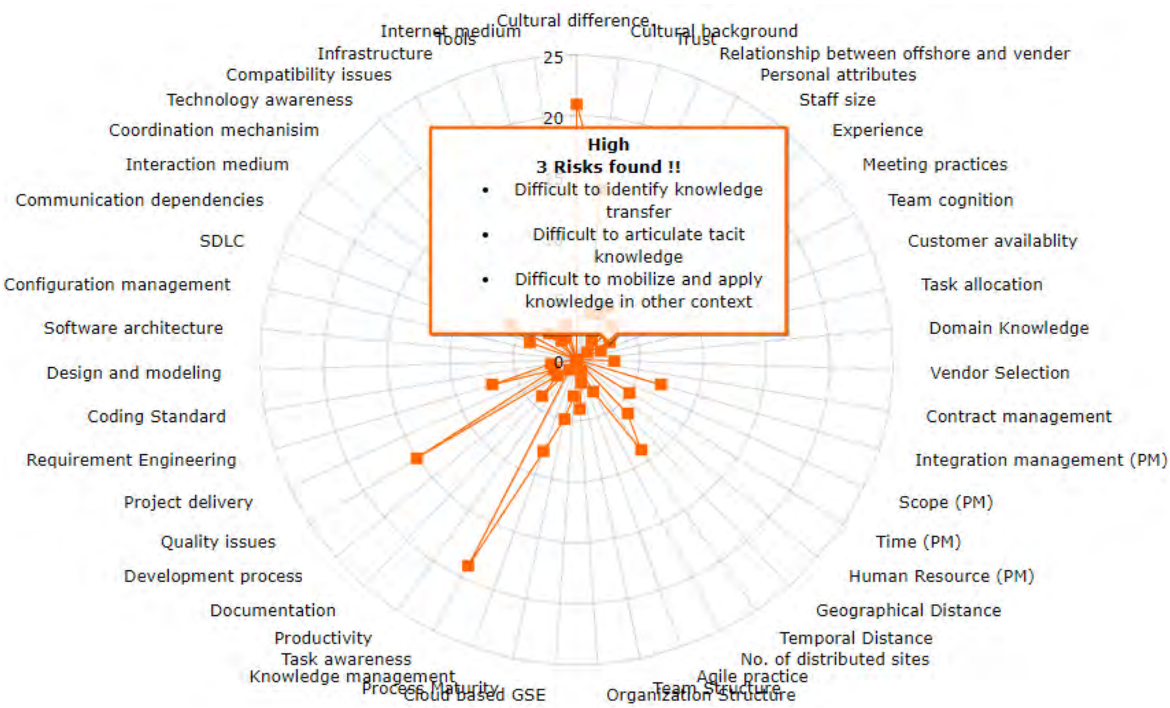


FIGURE 10. Radar chart for Siemen experience.

and show the absence of domain knowledge for DSD. The corresponding recommendation is also provided by DSS tool in order to control these risks.

Q2: How much decision about selection of control strategies is aligned with the decision of the case study?

The DSS provides a clear recommendation about the selection of control strategy against each aspect. These recommendations are based upon the impact of risks associated with each aspect. For example, in Philips case study, requirements engineering is a big problem as discussed in the case study.

30	Is different process of the development is documented properly within the organizations ?	Disagree	Task
31	Is different distributed sites or organizations is following proper development process?	Low [100]	Task
32	Is your organization or site is producing quality product?	partially agree sec 3.1.3 sec 3.1.4 [94],[91]	Task
33	Are organization , different site and customer is satisfy with project delivery and its performance?	medium [101]	Task
34	Is the requirement is complete from the start of the project ?	Medium	Task
35	Is organization or site have following same coding standard during development ?	Medium [95]	Task
36	Is organization is properly design and model the whole development process?	yes	Task
37	Is the Software architecture providing a good design for the system requirements?	Medium	Task
38	What is the degree of software configuration management in organization?	partially agree	Task
39	Is software development life cycle is followed in an organization?	Medium section 3.3.2 [94]	Task
40	What is the level of personal communication across sites?	Medium	Technology
41	Is the interaction medium is reliable for different sites?	High section 3.1 [94]	Technology
42	Are the coordination mechanism is appropriate across sites ?	Medium	Technology
43	Is people in organization or sites are familiar with technology used by them?	Medium	Technology
44	Are the technology used across sites is compatible with distributed sites?	High	Technology
45	Is infrastructure provided by the organizations or sites are appropriate?	Medium	Technology

FIGURE 11. **Tabulated control strategies for Siemens.**

In order to control risks associated with requirements engineering, a case study [89] provides a recommendation that there should be right involvement of the teams. Moreover, all the teams and their members must clearly understand requirement analysis. Different control strategies and rationale, depending upon the risks being reported by DSS tool to control risks, are associated with requirements engineering problem.

2) PROSPECTIVE CASE STUDY

The evaluation of prospective case study was carried out in two phases. The first phase involves the participation of some experts from the company. The primary purpose of the evaluation is to get their feedback on ease of use, content provided, quality of questions and options and set of rules. The participating experts provided recommendations for further improvement. Based on their feedback, the tool was further improved, for example, the list of prioritized risks in Radar chart as shown in **Fig. 12** was a suggestion of chief technical officer of Enabling system.

In the second phase, the tool was used by the decision maker of the company, Enabling System. This process takes almost 2 hours. It includes pre interviews, usage of tool and post interviews. Based on the answers to each question, a report is generated. The output of tool was analyzed and discussed again. The overall result is threefold.

- Radar chart represents risks assessment result of the company.
- Tabulated result shows the control strategies against identified risks.
- Discussion on results was provided by DSS for the company.

Radar chart shows assessment of risks in the company as shown in **Fig. 12.** The top chart shows the overall result of the assessment; whereas the bottom chart depicts assessment result of every dimension separately. The result of control strategies is shown in **Fig. 13.** The result of overall risks assessment shows that the most number of answers to the questions were reply-inward, meaning that limited numbers of risks are associated with aspects. After comparison of four charts, decision makers get the idea about the dimension that contains more number of risks. According to the result of the case study, various aspects have many risks, such as SDLC risks, design and modeling risks, quality issues and cultural background, where decision makers have to put in much attention to mitigate these risks.

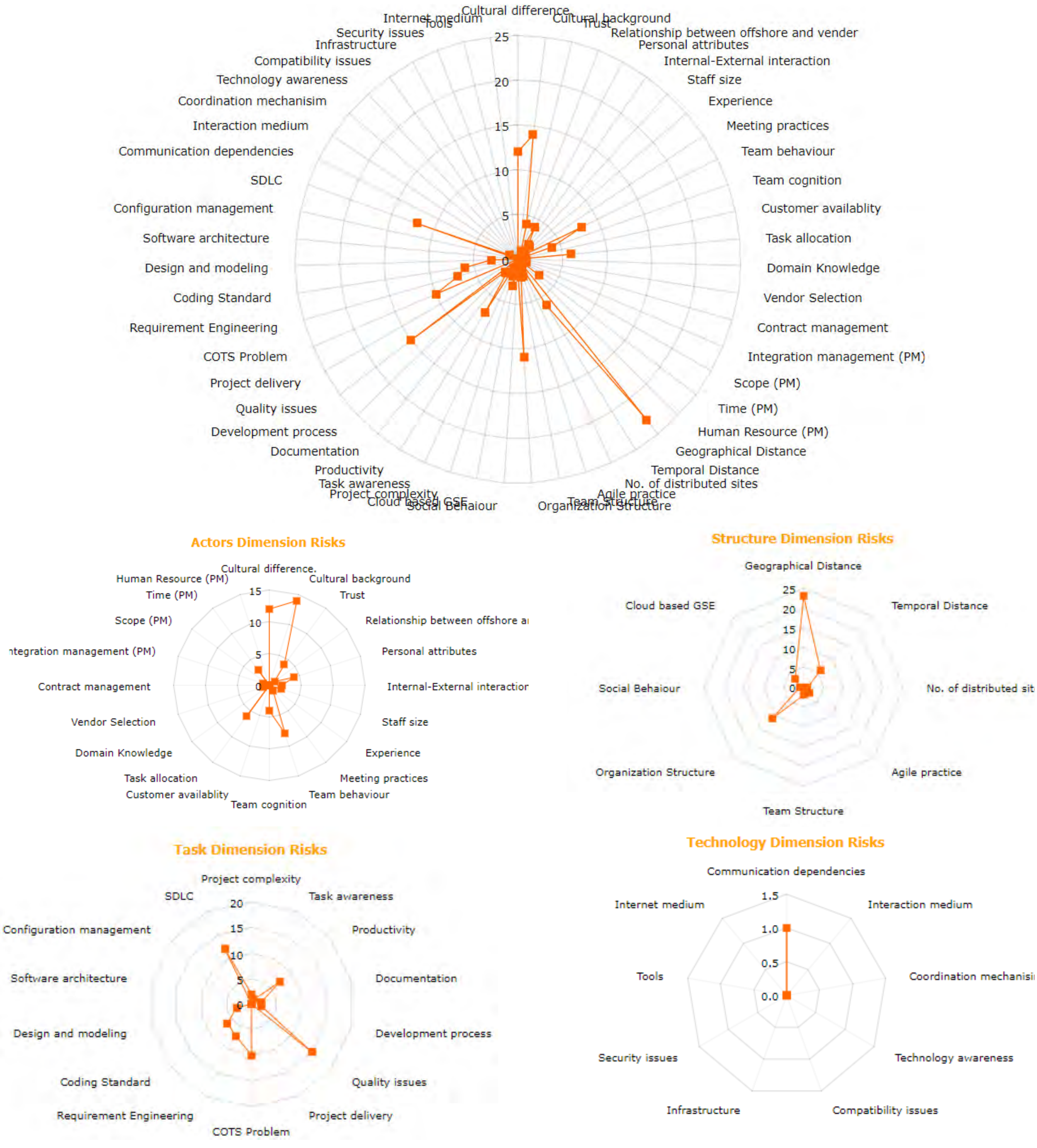


FIGURE 12. **Radar chart for company Enabling System with dimensions.**

The result of control strategies provides detailed visualization of the control strategy that is best suited to handle risks associated with each aspect. According to the graph, most of the answers are positive. The tool recommends that risks acceptance is best suited for many cases. The final report is about 17 pages long, where detail about each risk and relevant control strategy is presented.

Given below are the questions against which evaluation is performed.

15	Is vendor is capable for developing required product?	High	Actors
16	Is contract between sites or parties are concise and clear?	Agree	Actors
17	Is integration of different components of tasks is handled carefully?	High	Actors
18	Is scope of the project during development complete and clear?	high	Actors
19	Is project developed by distributed team is completed under planned time	partially agree	Actors
20	Is your organization have enough human resource to complete project?	High	Actors
21	How much the distance between two sites	High	Structure
22	What is the temporal distance between two distributed sites?	High	Structure
23	How many sites are involved and what is the distance between them?	Low	Structure
24	Is agile practices followed in different distributed sites?	partially agree	Structure
25	What is the level of team structure across sites?	High	Structure
26	What is the structure of the organization?	Same organization	Structure
27	What are the social attributes of different team members with in the organizations?	High	Structure
28	Is organization is fully support cloud base architecture for different sites?	partially	Structure
29	Is the complexity is faced by the project across sites?	yes	Task
30	How much awareness of task or work among different project manager across sites ?	High	Task
31	What is the degree of productivity across sites in your organization?	Medium	Task
32	Is different process of the development is documented properly within the organizations ?	Partially agree	Task
33	Is different distributed sites or organizations is following proper development process?	Medium	Task
34	Is your organization or site is producing quality product?	partially agree	Task
35	Are organization , different site and customer is satisfy with project delivery and its performance?	High	Task

FIGURE 13. Tabulated control strategies of enabling system.

Q1: How much DSS supports decision making in risk assessment in DSD?

The site of the company in Pakistan has no proper method for risk management in distributed development. Time zone problem is common and many risks associated with time zone occur. Site in Pakistan only possess basic knowledge on risks assessment. They mainly focus on meetings with offshore partners to discuss ambiguities and try to resolve them. The employment of DSS tool may have a direct impact on the opinion of the decision maker. Remarks for the tool are significant and indicated below.

"*Recommendations provided by DSS were very useful. It provides us all necessary information about risk assessment. It will be helpful in future for outsourcing of products*".

"*If we were in a need of new offshore company then definitely we will use it*".

"*It was very understandable, to the point questions, no unnecessary fabrication, and the results were very interesting*".

The decision maker of the company maintains that DSS provides detail information explicitly. It provides details of questions and answers of each aspect. It is easily understandable. He stated that if they were in a need for a new offshore company, then for risks assessment, they will use this system.

DSS showed that requirement engineering and different coding standards have a significant number of risks associated with these aspects. However, there are not too many problems with a number of distributed sites and following agile practices. This information may prove to be helpful to the company in various situations; for example, on the basis of this information, the company can allocate resources to control risks associated with requirement engineering and different coding standards.

Q2: How much DSS supports decision making for selection of control strategies?

The company has only basic knowledge about control strategies. Before using DSS, they stated that most of the risks are not documented properly. Risks are tried to be mitigated by different activities such as late sitting working to overcome the challenges of time zone problem. The DSS provides strong recommendations according to the company's context Project manager and CTO are satisfied with recommendations. They find it useful for future development activities. Most of the recommendations are related to risk acceptance for this company.

Q3: How practical is the DSS for decision making in risks management in DSD.

To answer this question, two more questions were asked. 1) Does DSS assess risks adequately? The answer is "*yes it does. The quality of questions was excellent, the answer was good enough but they should improve to make the final decision because out sourcing a product is a very risky decision. Company future depends on the product*." The second question was open-ended. 2) Will you use DSS again? The answer is "*not at the moment because currently we have active in-house development and do not need to outsource our work in near future*". The answers have suggested that DSS is helpful in risk management in DSD.

3) THREATS TO VALIDITY OF CASE STUDIES

In this section, potential threats that can damage validity of case studies evaluation are discussed. Some threats are associated with both retrospective and prospective case studies. In order to ensure the validity of these case studies, Table 9, points out some potential threats and discusses measures that are used to mitigate them. In retrospective case we evaluated our DSS against the case studies already published in literature. A potential threat here was missing information which can affect result. In order to address this threat we selected highly cited case studies from literature. This ensured that there is a lot of information available on them. To overcome threats related to the prospective case, we asked open ended questions in interviews. This ensured complete and thorough responses from the participants thus minimizing the threat related to missing information.

V. RELATED WORK

Many studies discuss risks in Distributed Software Development. Some of them discuss techniques and approaches for risks assessment in DSD. These studies also provide best-suited control strategies to avoid or handle these risks. These approaches have already been discussed in Section II. This study can be considered as a complementary study to already existing studies. To develop a Decision Support System, knowledge from different databases is extracted to clearly define questions, possible options, and their rules. Most of the present approaches to risks assessment do not include automatic support. Due to increasing interest in DSD, it is necessary to have effective and automatic support for risk assessment in distributed software development. Some notable characteristics of DSS tool are its easy adaptation and use, and scalability.

The literature contains extensive work on risk management in DSD. Verner *et al.* [3] presents results of different SLRs on risks and their mitigation on DSD. A total of 37 studies was found, 85 risks were extracted and 77 mitigation advice were put forth. This study can also be considered as an integrative study; however, it does not cater the circumstances in which certain problems can occur. Lamersdorf *et al.* [5] proposed a rule-based model for risk identification in GSD. These rules are made on the basis of past experience projects and interviews with practitioners. This model helps project managers to assess risks individually. However, the model does not provide guidelines on the ways to overcome challenges associated with certain aspects. Presson *et al.* [48] proposed integrative framework for risk assessment in DSD. The methodology includes an intensive literature review on GDSD, considering 72 articles. Risks, resolution techniques and the heuristics were derived from these studies. A web-based tool has also been developed for different practitioners. Four different evaluations were conducted to validate the proposed technique. However, this study does not provide information on conditions under which certain risks can occur.

In general, there are a number of qualitative and quantitative studies focusing on risks in DSD. Some of them reported experience in DSD and discuss risks that they faced [5], [17], [33]. Other studies focus on case studies research [16], [22], [68], [74] and most of them are based upon literature review [20], [21], [44], [69]. The studies provide a number of risks and control strategies; however, most of them do not provide guidelines or explanations on circumstances under which certain risks can occur. They also do not give reasonable information on best-suited control strategies. This process is very important for the assessment of project risks. Hence, proposed DSS has the ability to define set of rules and descriptions of circumstances in which certain problems can occur and provide suitable management strategy. VI depicts the brief comparative analysis of some existing studies from literature with our study.

A large number of studies discuss decision support systems (DSS) and their applications. Pick and Weatherholt [99] provide a detailed discussion on different DSSs and their evaluation processes which were already proposed in the literature. A DSS can be active, passive or cooperative. An active DSS explicitly recommends solutions to decision maker; the passive DSS does not provide clear suggestions or solutions, and cooperative DSS allows the decision maker to customize decision suggestions. In this study, the DSS helps decision makers for risk assessment and selection of suitable control strategies in DSD. This DSS is an active and cooperative. Furthermore, this DSS is knowledge-driven, which takes action depending on the questions, answers and their related rules. It is a web-based tool and can be accessed by any user.

The DSS is vastly used and applied for planning and controlling of projects [100]. SimaPro 8 software is a tool, supporting decision making for new products' design based on the defective products management [101]. The DSS is used for the selection of suitable and aligned strategies from among the enterprises that belong to the collaborative network [102]. Andres and Poler [102] proposed a DSS for modeling and management of project risks. This model provides support for risk evaluation and their periodization. It also helps project managers in taking responses against identified risks.

QPLAN [103] is a system developed for evaluation of planning quality. It is used to make optimal decision to approve project plan for software development. It is an empirical and evidence-based tool. The feedback from 20 project managers is used for validation of QPLAN. This tool may help to reduce planning biases and improve project performance. Project managers have different opinions; however, software industry that follows waterfall methodology finds QPLAN more effective than agile methodology. However, the currently proposed tool is used for risk assessment and selection of management in DSD.

VI. CONCLUSION

Risk assessment and management in Distributed Software Development is a well-researched area. However, problem is that either researchers have only considered a limited number of risks that are specific to a certain context or have provided generic framework without considering contextual factors of companies. Although, there are different rules and guidelines on risk management mentioned in literature but they are spread across different publications. This makes it difficult to process them manually.

To overcome these challenges, we have proposed a Decision Support System for managing risks in DSD. In order to create knowledge base for the proposed DSS, we conducted a systematic literature review. This resulted in 49 identified aspects and 524 risks associated to these aspects. The identified aspects are categorized into four dimensions of Leavitt organization model. Building on the results of SLR, 53 questions and 163 rules are derived, which are being used for the decision-making process in DSS. This DSS is also implemented as a tool and is available at www.risksupports.com. The proposed DSS is empirically evaluated using retrospective and prospective case studies. From the result of validation of these case studies, it can be concluded that DSS is reliable and helpful for decision makers in making decisions during DSD risk management.

Various areas of future work have been identified. Proposed DSS can be linked to different stages of planning in a DSD project. This could involve identifying variations in DSS output at different stages of the project. Moreover, it would be interesting to quantify and correlate the benefits of DSS in a real project setting. This could be done by estimating the cost/benefit of each risk and its control strategy identified using DSS, and comparing it for risks identified without using this DSS.

Furthermore, it can also be extended by adding the feature of task allocation across sites in distributed development depending upon the results of risk assessment.

One limitation of this study, as discussed in threats to SLR validity section, is the subjectivity or selection bias of the authors in identifying and defining aspects, risks, and control strategies. As already discussed, different measures have been taken to minimize this selection. Moreover, two types of case studies have been conducted to validate the proposed DSS.

APPENDIX A

Q1: What can be the cultural difference between distributed sites?

a) Low socio-cultural difference among sites.

b) High socio-cultural difference among sites

Q2: What is the cultural background of organizations?

a) Same organization b) Different organization

Q3: What is the trust level among employees at distributed sites?

a) Low b) Medium c) High

Q4: What is the degree of relationship between clients and vendors?

a) Close b) Medium c) Low

Q5: What are the employee's skill levels at distributed sites?

a) Low b) Medium c) High

Q6: What is the level of interaction between internal and external elements?

a) High b) Medium c) Low

Q7: Is your staff fully competent with you or organization?

a) Strongly agree b) Agree c) Disagree

Q8: What is the experience of employees in your organization?

a) High b) Medium c) Low

Q9: When higher authority and project managers meet about issues?

a) Regularly b) Upon special event

c) Arrange meeting

Q10: What is the degree of team behavior within different sites?

a) Low b) Medium c) High

Q11: What is the team cognition level between dispersed teams?

a) Very high b) High c) Low

Q12: How many customers are available during the software development process?

a) High b) medium c) Low

Q13: Is task divided into sub-tasks and allocated to sites in a proper manner?

a) Agree b) Partially agree c) disagree

Q14. What is the degree of domain knowledge of particular site?

a) High b) Medium c) Low

Q15: The vendor you select is capable of developing a product?

a) High b) Medium c) Low

Q16. The contract between sites or parties is concise and clear?

a) Agree b) Partially agree c) Disagree

Q17. Is integration of different components of tasks handled carefully?

a) High b) Medium c) Low

Q18. Is scope of project complete before the start of development?

a) High b) Medium c) Low

Q19. Is project developed by distributed sites completed under planned cost?

a) Agree b) Partially agree c) Disagree

Q20. Does your organization have enough human resource to complete the project?

a) High b) Medium c) Low

Q21. How much distance between distributed sites?

a) High b) Medium c) Low

Q22. What is the temporal distance between distributed sites?

a) High b) Medium c) Low

Q23. How many sites can be involved in distributed development?

a) High b) Medium c) Low

Q24. Is agile practices followed in different distributed sites?

a) Agree b) Partially agree c) Disagree

Q25. What is the level of team structure across sites?

a) High b) Medium c) Low

Q26. What is the structure of the organization in distributed sites?

a) Same organization b) Different organization

Q27. What are the social attributes of different team members with in the organizations?

a) High b) Medium c) Low

Q28. Is organization fully support cloud base architecture for different sites?

a) Fully b) Partially c) Not using cloud

Q29. What is the process maturity of different sites?

a) High b) Medium c) Low

Q30. What is the degree of knowledge management in your organization or sites?

a) High b) Medium c) Low

Q31. Is complexity faced by the project across sites?

a) Yes b) No

Q32. How much is awareness of task among different project managers required across sites?

a) High b) Medium c) Low

Q33. What is the degree of productivity across sites in your organization?

a) High b) Medium c) Low

Q34. Is different process of the development documented properly within the organizations?

a) Agree b)Partially agree c)Disagree

Q35 Are distributed sites following proper development processes?

a) High b) Medium c) Low

Q36. Your organization or site is producing a quality product?

a) Agree b) Partially agree c) Disagree

Q37. Are distributed sites or is customer satisfied with project delivery and its performance?

a) High b) Medium c) Low

Q38. Are sites using component based software development methodology to build software?

a) Fully b) Partially

Q39. Is the requirement complete from the start of the project?

a) High b) Medium c) Low

Q40. Is organization or site having following same coding standard during development?

a) High b) Medium c) Low

Q41. Is organization properly designed and models the whole development process?

a) Yes b) No

Q42. Is software architecture providing a good design for the system requirements?

a) Agree b) Partially agree c)Disagree Q43. What is the degree of software configuration management in an organization?

a) High b) Medium c) Low

Q44. Is software development life cycle followed in an organization?

a) High b) Medium c) Low

Q45. What is the level of personal communication across sites?

a) High b) Medium c) Low

Q46. Is the interaction medium reliable for different sites?

a) High b) Medium c) Low

Q47. Is the coordination mechanism appropriate across sites?

a) High b) Medium c) Low

Q48. Is internet medium reliable across distributed environment?

a) Agree b) Partially agree c) Disagree

Q49. Are people in organization or sites familiar with the technology used by them?

a) High b) Medium c) Low

Q50 Is the technology used across sites compatible with distributed sites?

a) High b) Medium c) Low

Q51. Is infrastructure provided by the organizations or sites appropriate?

a) High b) Medium c) Low

Q52. What is the degree of security provided by the organization?

a) High b) Medium c) Low

Q53 Are the tools compatible with different distributed sites?

a) High b) Medium c) Low

APPENDIX B

Questions asked to assess Decision Support System (DSS)

Q Your experience in distributed software development**?**

Q What type of risks occurs during distributed software development?

Q: What are your methods for risk management in distributed software development?

Q: What do you think about the validity of recommendations provided by DSS?

Q: How much practical DSS is?

Q: Will you use DSS again?

Q: What is your observation about the quality of questions, answers and provided recommendation?

Q: Does DSS assess risks, adequately?

Q: Do you think DSS can provide a competitive advantage to your organization?

Q: What do you think about the recommendations provided by DSS for controlling risks?

Q: What do you think DSS will enhance your knowledge about risks management?

Q: Do you think DSS can be beneficial for you and your organization?

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ADEEL ASLAM received the master's degree in computer science from the COMSATS Institute of Information Technology (CIIT), 2014. His area of specialization is software engineering and research interests include software project management and risk management. He is currently a Researcher with the Software Engineering Research Laboratory, CIIT.

NAVEED AHMAD received the doctoral degree in engineering design from the University of Cambridge, England. He joined the COMSATS Institute of Information Technology (CIIT) in 2011. He is serving as an Assistant Professor with the Computer Science Department, CIIT. His research interests include change management, process management, risk management, enterprise information systems in particular enterprise resource planning software. He is member of research groups on software engineering and mobile application development in CIIT.

TANZILA SABA received the Ph.D. degree in document information security and information management from the Faculty of Computing, Universiti Teknologi Malaysia, Malaysia, in 2012. She is currently serving as an Assistant Professor with the College of Computer and Information Sciences, Prince Sultan University, Riyadh, Saudi Arabia. Her research interests include intelligent data mining, forensic documents analysis, and information security. She won the 2012 Best Student Award in the faculty. Due to her excellent research achievement, she is included in Marquis Whos Who (S & T) 2012.

ABDULAZIZ S. ALMAZYAD received the Ph.D. degree in computer engineering from Syracuse University, Syracuse, NY, USA. His areas of expertise are computer networks, data communication, information and network security, systems modeling and simulation, information systems, and machine learning.

AMJAD REHMAN received the Ph.D. degree in image processing and pattern recognition from Universiti Teknologi Malaysia, Malaysia, in 2010. During his Ph.D., he proposed novel techniques for pattern recognition based on novel features mining strategies. He is currently conducting research under his supervision for three Ph.D. students. He is the author of dozens of papers published in international journals and conferences of high repute. His keen research includes information security, data mining and documents analysis, recognition.

ADEEL ANJUM received the Ph.D. degree (Hons.) in 2013. He is currently an Assistant Professor with the Department of Computer Sciences, COMSATS Institute of Information Technology Islamabad Campus. He has several publications in international conferences. He is also the author of a book on data privacy. His area of research is data privacy using artificial intelligence techniques. He serves in the technical program committees of various international conferences.

ABID KHAN received the Ph.D. degree from the Harbin Institute of Technology. He is currently an Assistant Professor of computer science with the COMSATS Institute of Information Technology, Islamabad. His research interests include the security and privacy of cloud computing (outsourced storage and computation), security protocols, digital watermarking, secure provenance, and information systems.