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A Tacit-Knowledge-Based Requirements Elicitation Model Supporting COVID-19 Context

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ABSTRACT Effective software requirements elicitation plays a vital role in the success or failure of a project. However, ambiguity in the requirement's statements indicate the presence of a tacit knowledge, which ultimately act as a root cause of critical complications in later stages of software development as user's needs might remain hidden. Additionally, the existence of numerous stakeholders escalates the problem as their perceptions may contrast mainly due to their experiences and roles in a specific application domain. Hence, witlessness of relevant stakeholder(s) and ambiguous requirements cause the compromise for a product quality. Eventually, it paves the way towards the failure of a project. Furthermore, COVID-19 has affected all walks of life, more specifically requirements elicitation process as it heavily depends on human-to-human interaction. Motivated by this, current study aims at identifying the requirements elicitation techniques and challenges through a systematic literature review protocol. Furthermore, we have performed an exploratory study to identify the traditional elicitation techniques that can be used specifically for eliciting the tacit requirements. Additionally, we validate the top 15 critical challenges in a normal and pandemic scenario. To validate the result's authenticity and legitimacy, appropriate statistical tests have been applied on the obtained results. Based on the attained results, it is observed that transfer of tacit knowledge remains a most crucial challenge. To effectively handle the tacit knowledge challenge, we propose a novel conceptual model supporting COVID-19 context. Similarly, we employ expert-validation mechanism for empirically evaluation of the proposed conceptual model. Moreover, the current study provides the guidelines for the practitioners to mitigate the highlighted effects on the requirements elicitation process during current pandemic time. Finally, we believe that proposed conceptual model supports the practitioners in effectively gathering the tacit-knowledge based requirements in the COVID-19 context.

INDEX TERMS Requirements elicitation, challenges, tacit knowledge, tacit knowledge techniques, empirical investigation, systematic literature review, conceptual model.

I. INTRODUCTION

From the last few decades, colossal inflation of demand for software systems has caused expeditious growth in software development. Hence, software development is getting huge contemplation of researchers, starting from software systems to embedded systems, AI, and mobile applications, and so on. Due to the volatile user requirements, the development of a software system entails many risks. Due to this fact, Requirements Engineering (RE) is considered as the most important step of software development lifecycle [1]. Based

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on the previously conducted studies, it has been observed that almost 60% of failures occur due to poor RE. Notice that RE mainly concerns with the establishment of goals, constraints, and properties of the system along with the discovery of users [2].

RE consists of several activities including requirements elicitation/ gathering, requirements analysis, requirements specification, requirements validation, and management [3]. Requirements' elicitation is the first activity of the RE stage. In real scenarios, the requirements elicitation process is a multi-dimensional in nature, i.e. somehow complex, and iterative activity that profoundly relies on the requirement engineer's communication skills [4], [5]. Moreover,

the cooperation and commitment of other stakeholders also plays a crucial role during RE process. The communication barrier is highlighted as one of the main problems faced by software development project teams [6]. The important point that needs to be communicated clearly to stakeholders might remain opaque to them. Generally, this situation goes unnoticed during the elicitation process, and this may ultimately fail a project [7]. The establishment of the system's goals by capturing the users' needs is critical as "the knowledge is tacit" in most cases [8]. The quality and eminence of requirements are significantly prejudiced by the techniques used while eliciting the requirements. Elicitation is mainly concerned with mining and learning users' actual needs and, after that, communicating them to the developers [9]. The requirements elicited from the stakeholders are considered as basis of engineering the system's architecture and design, and development plan [8]. The most common issue in requirements elicitation phase is that the stakeholders or customers have a vague idea about the required/desired functionalities. To handle this issue, it is suggested that the requirements engineer must elicit the requirements so that that vague information could be turned into a formally documented requirements specification document [10].

Tacit knowledge in communication is often professed as a major hurdle or obstacle for knowledge transfer, which could lead to unclear and incomplete requirements elicitation process [10], [11]. Ultimately, it plays the prominent role in the success or failure of project. Thus, eliciting the most accurate requirements from the relevant stakeholders, and also transfer of "*tacit knowledge*" remains important for success of a software project [12]–[14]. However, to the best of our knowledge, current state-of-the-art lacks in categorization of the challenges, and providing a control process to mitigate them in context of transfer of "*tacit knowledge*". Therefore, there is need to identify and categorize all the challenges that negatively affect the software elicitation process. Moreover, a conceptual model in the context of identification of relevant stakeholder and transfer of tacit knowledge is needed.

COVID-19 pandemic has affected all the human activities and has evoked an era of agility [15]. As elicitation process mainly depends on the interaction of requirements engineer and stakeholders. Notice that the stakeholders are not necessarily the human entities but can be the organizational surroundings or environment where the intended system is to be utilized [16]. Evidently, existing work lacks in the identification of challenges that are being highlighted during the pandemic time. Therefore, there is a need to identify the challenges during requirements elicitation process in COVID-19 scenario and to provide a set of guidelines effective in mitigate the impact of the identified challenges.

Motivated by this, we have performed Systematic Literature Review (SLR) to identify the challenges that affect requirements elicitation process. After identification, the challenges have been categorized and prioritized. To reduce the biasness of the results, quality-oriented review is performed. Keeping in view of quality, the conducted SLR

observes to the principles of transparency, accountability, and audibility. Following Research Questions (RQs) are designed to achieve the objective of current research:

RQ1: What are various requirements elicitation techniques employed by requirements engineers?

RQ1.1: What are specific techniques used by the requirements engineers to elicit the Tacit Knowledge?

RQ2: What are various challenges which affect negatively on the elicitation process during software development?

RQ2.1: What is categorization and prioritization of various challenges that affect the elicitation process?

RQ3: What are various challenges that negatively affect by COVID-19 Pandemic during requirements elicitation?

RQ4: How the effect of identified challenges during requirements elicitation process can be mitigated in COVID-19 Pandemic context?

The main contributions of this research work are as follows:

- i. Empirically investigates the tacit-based requirements elicitation techniques.
- ii. Provides a categorization and prioritization of challenges through frequency analysis.
- iii. Presents a conceptual model that unfolds the tacit knowledge during requirements elicitation process.
- iv. Validates the proposed conceptual model through expert-based validation technique.
- v. Highlights the challenges related to requirements elicitation process during the COVID-19 pandemic, and also provide the guidelines for the practitioners to mitigate the challenges.

The remaining part of this paper is organized as follows: Section II provides a detailed overview of research motivation for current research work. Section III describes the adopted research methodology; section IV presents the results concerning the formulated research questions, while section V describes the discussion on the basis of research objectives. The proposed conceptual model is presented in section VI. Section VII provides the validation of proposed conceptual model, while section VIII illustrates the research implications. Section IX outlines the threats to validity. Finally, the conclusion is provided in section X.

II. RESEARCH MOTIVATION

Requirements' elicitation is considered as intricate, intensive, and multi-disciplinary process. This is due to the reason that requirements elicitation aims at gathering the user's needs and fulfill the stakeholder's objectives [17]. When the potential stakeholders try to elaborate their requirements of intended system, they are basically translating their tacit knowledge into the explicit knowledge [18]. Notice that tacit knowledge is basically a kind of knowledge required for better development of a product, which a client has but unable to articulate/share with the analyst [4].

Tacit requirements are hard to communicate, related to domain of the system, user's own knowledge, and may change during phases of development [19]. Eliciting tacit

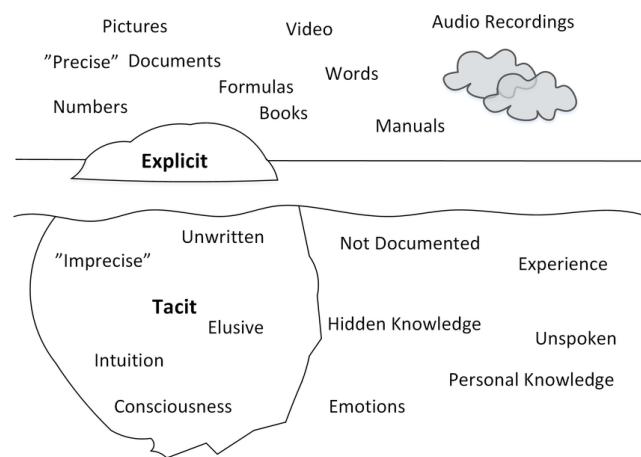


FIGURE 1. Tacit vs. Explicit knowledge [20].

knowledge is similar to the process of gathering tacit requirements [20].

Figure 1 illustrates that the knowledge is divided into two categories: (i) tacit knowledge, and (ii) explicit knowledge. Tacit knowledge is regarded as hard to document, which personnel use to perform certain tasks and to take verdicts or decisions [21]. Experts distributed the knowledge of an individual with the extensively agreed division of 90% tacit and 10% explicit [20]. This division of knowledge percentage evidently creates the problem for requirements engineers to elicit the precise requirements from stakeholders.

The term “tacit knowledge” was introduced by Polanyi (1966), who identified the body of knowledge that is generally challenging to communicate [13]. The presence of tacit knowledge can be a root cause of complications in the later stage of software development as user’s needs might remain hidden. Additionally, the existence of numerous stakeholders escalates the problem as their perceptions, interests and expectations may contrast due to their experiences and their role in the specific application domain [22].

Whenever a stakeholder expresses the element of information, ambiguity occurs as the meaning associated with that element of information may differ from the meaning intended by the stakeholder. This ambiguity indicates the presence of tacit knowledge [23].

It has been observed that traditional methods for elicitation are failed to expose and discover the critical requirements as these techniques predominantly focus on technical aspects only [24], [25]. Some of the traditional elicitation techniques include interviews, questionnaires, scenarios, and prototypes. The questionnaire-based survey is considered as one of the effective techniques used by the requirements analysts to elicit the data during pandemic era where face-to-face interaction is not possible [28].

Evidently, to have a quality product, true requirements are needed and eliciting the necessary requirements remains a major challenge in RE context. Some of the core challenges are communication challenges, lack of stakeholders’ interest,

and capturing authentic users’ needs [26], [27]. It has been found in one of the reported studies conducted by Yaseen and Ali [18] that right type of collaborative tool for communication along with the proper cooperation is mandatory to capture the proper requirements from stakeholders.

Kania *et al.* [27] mentioned the challenges that greatly impacts during requirements elicitation process. The reported challenges are lack of user’s confidence, and lack of trust between stakeholders and analysts. The trust between humans is built due to eye contact [29]. Several studies have been conducted on lack of contact in case of video calls. The researchers have also suggested some solutions to improve it [31].

Kniffin *et al.* [30] pointed out accessibility issues to an appropriate space for office purpose at home. Lack of dedicated workspaces at home for office work negatively affects the efficiency of employees [32], [33]. During COVID-19 pandemic, the interference in concentration of employees has caused serious challenges and brought problems in sharing tacit knowledge [34].

Hence, the facts described above have motivated us to work on this aspect. Keeping in mind the importance of requirements elicitation techniques and challenges, more specifically in the context of identification of relevant stakeholder and transfer of tacit knowledge, we observed that the literature has seen limited work on tacit-based requirements context. Moreover, in current pandemic scenario, no literature has been found that has raised the effect of pandemic restrictions on requirements elicitation process. However, it is of paramount importance to detect and identify the challenges of requirements elicitation process and to categorize them, accordingly. This categorization helps requirements engineers and project managers to mitigate the effect of identified challenges. However, the conceptual model in context of identification of relevant stakeholder and unfolding of tacit knowledge helps the industry practitioners in eliciting the most accurate requirements.

III. RESEARCH METHODOLOGY

SLR protocol is adopted to answer the targeted research questions, and to achieve the research objectives. Notice that process of SLR is different from a normal literature review process. SLR is useful in gathering the data systematically in an arranged and unbiased manner [26]. To perform SLR in an efficient way, we followed the guidelines of Kitchenham *et al.* [26]. This process consists of three main phases and each phase consists of different sub-phases. All these sub-phases are discussed in their respective sections. Figure 2 displays the detailed research methodology adopted for this research work. Similarly, Figure 3 illustrates three main phases of the conducted SLR.

The adopted research methodology consists of five different phases (Figure 2). In problem formulation phase, we started with the extensive general literature review to identify the research gap and formulated of problem statement. Current research targets the problem associated with

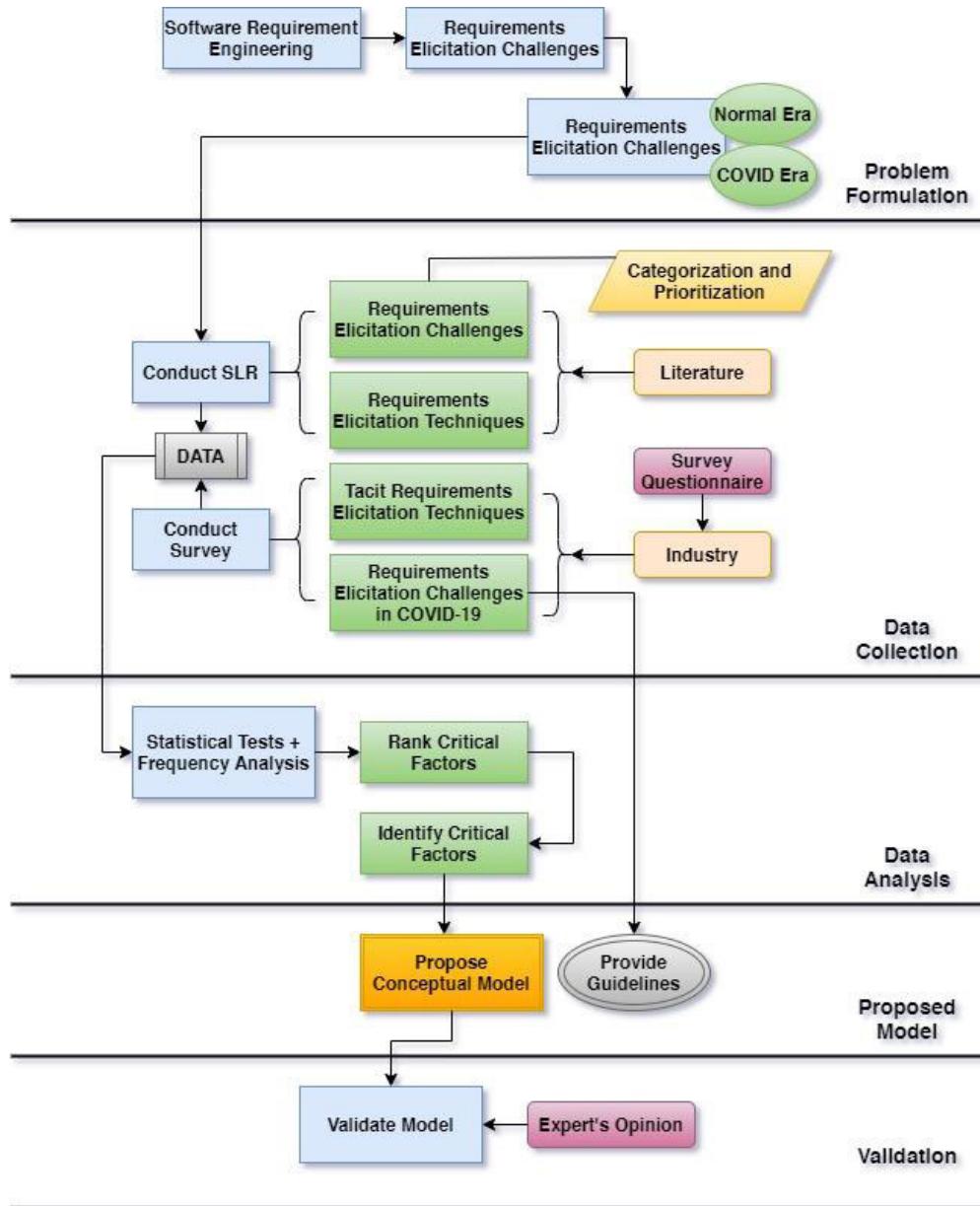


FIGURE 2. Detailed research methodology.

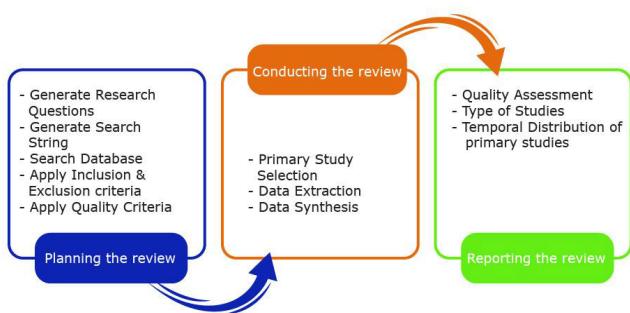


FIGURE 3. Three main phases of adopted SLR.

the transfer of tacit knowledge in requirements elicitation phase during COVID-19 Pandemic era. In data collection

phase, we performed a SLR to obtain data in an organized and systematic manner. To validate the obtained data, an empirical study was performed targeting the practitioners from industry. In data analysis phase, we applied various appropriate statistical tests to highlight the most critical challenges. In the proposed model phase, we presented the conceptual model according to the obtained findings and goals. Furthermore, the proposed conceptual model is validated through expert's opinion in the validation phase. The following sections present the main phases of SLR.

A. PLANNING THE REVIEW

The first phase of the SLR consists of following activities:

- Generation of research questions.

- ii. Selection of most appropriate data source (search) repositories.
- iii. Generation of search string.
- iv. Defining appropriate inclusion and exclusion criterion for paper selection.
- v. Setting and applying quality assessment criteria.

The following sections provide comprehensive discussions about the above-mentioned activities of planning phase of the conducted SLR:

1) RESEARCH QUESTIONS

To achieve the targeted research objective, we devised the following Research Questions (RQs):

RQ1: What are various requirements elicitation techniques employed by requirements engineers?

RQ1.1: What are specific techniques used by the requirements engineers to elicit the Tacit Knowledge?

RQ2: What are various challenges which affect negatively on the elicitation process during software development?

RQ2.1: What is categorization and prioritization of various challenges that affect the elicitation process?

RQ3: What are various challenges that negatively affect by COVID-19 Pandemic during requirements elicitation?

RQ4: How the effect of identified challenges during requirements elicitation process can be mitigated in COVID-19 Pandemic context?

2) DATABASE SELECTION

To find the relevant studies published in well reputed peer-reviewed journals, conferences, we selected multiple database preferences recommended by Arif *et al.* [37]. We finalized the total 4 out of 5 databases, as it has been observed that almost all of the potential studies were retrieved from Wiley, IEEE Xplore, SpringerLink, and Science Direct. However, to verify the comprehensiveness of the identified primary studies, we cross checked them through Google Scholar. Hence, the selected databases are Wiley, IEEE Xplore, SpringerLink and Science Direct.

3) SEARCH STRING

Search string is designed keeping in view of the targeted research objective and devised RQs. The search string comprises of the selected keywords that are being used in the current research. The keywords and their synonyms were selected on the basis of already available studies in the context of current research [26]. The search terms were divided into five categories (i) Requirements Elicitation (ii) Challenges (iii) Techniques (iv) Model or framework and (v) Software Development. Moreover, the search strings were further customized according to the targeted databases due to the different searching mechanisms, strategies and restrictions of the databases. Table 1 highlights the tailored search strings for each of the selected databases.

4) INCLUSION CRITERIA

A review protocol is incorporated in current research work for a definite strategy to search and determine the studies.

TABLE 1. Tailored search string.

Database	Search Strings
Wiley	(Elicitation OR Requirement Gathering OR Requirement Elicitation) AND (Method OR Technique) AND (Problems OR Challenges OR Issues) AND (In-house OR Onshore OR Onsite) AND (Model OR Framework) AND (Software Application OR Software Development)
IEEE Xplore	(Requirement Elicitation OR Requirement Gathering OR Requirement Acquisition) AND (Challenges OR Issues) AND (Technique OR Method) AND (Software Application OR Software Development)
SpringerLink	(Elicitation OR Requirement Gathering OR Requirement Elicitation) AND (Method OR Technique) AND (Problems OR Challenges OR Issues) AND (In-house OR Onshore OR Onsite) AND (Model OR Framework) AND (Software Application OR Software Development)
Science Direct	(Requirement Gathering OR Requirement Elicitation) AND (Method OR Technique) AND (Challenges) AND (In-house) AND (Model) AND (Software Application OR Software Development)

Benchmark has applied to the data which is extracted from the search repositories through designed query [40]. Following are the inclusion criteria that are implemented in this study.

- IC1: The potential research articles must be written in English.
- IC2: The research articles should be published in Journal/conference papers.
- IC3: Research articles consisting of Requirements Elicitation Issues or challenges.
- IC4: Research articles consisting of Requirements Elicitation Techniques.
- IC5: Research articles should cover the targeted research objectives.
- IC6: Research articles that have followed appropriate standard research methodology.
- IC7: Research articles that are not identical of any other article.
- IC8: Research articles that published after 2016 to date.

5) EXCLUSION CRITERIA

The elimination benchmark has been applied to the studies that are to be extracted from the database repositories as a result of query [42]. Papers were included from 2016 to 2021, and the rest were excluded.

- EC1: Research articles that are written in languages other than English.
- EC2: Research articles that are published before 2016.
- EC3: Research articles that have irrelevant titles and abstracts.
- EC4: Research articles containing irrelevant information in context with research questions.
- EC5: Research articles whose methodology is not clearly defined.
- EC6: Research articles having unclear data collection methodology.
- EC7: Research articles possessing ambiguous data validation methodology.

6) QUALITY ASSESSMENT FOR SELECTED STUDIES

Quality assessment is a compulsory measure of an SLR. As stated earlier, we have devised a search string for each database repository to target the potential primary studies (Table 1). To guarantee the SLR's overall quality, we have targeted well known and reliable database repositories, only. Moreover, the selection criteria itself is a quality measure consisting of a checklist.

For assessing the overall quality of targeted studies, a quality assessment checklist was generated. Quality Assessment Criteria (QAC) allows determining the most relevant articles inside the idyllic scrutiny space.

The following questions were generated to evaluate the quality of the selected studies:

QC-1: Does the objectives of the proposed research study discussed?

QC-2: Is the research methodology used in selected article clearly defined?

QC-3: Does the study explicitly focus on Requirements Elicitation Issues?

QC-4: Do the results of the proposed study match the targeted research objectives and research questions?

QC-5: Does the appropriate methods are used to combine the studies?

Following are the assessment criteria for the checklist questions:

- i. “1” point for the articles that address the appropriate answer.
- ii. “0.5” points for the articles that address the fractional answer.
- iii. “0” points for articles not addressing the desired checklist questions.

APPENDIX B illustrates the quality assessment of each selected primary study.

B. CONDUCTING THE REVIEW

In phase 2 of conducted SLR, we performed the review by applying the search string query to relevant databases to find the primary studies. The generic process of conducting the review process is illustrated in Figure 4. To extract the primary studies, standard approaches were being used. After the extraction phase, studies were synthesized according to

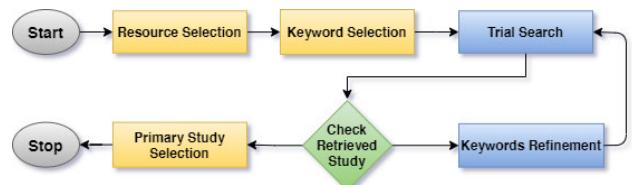


FIGURE 4. Generic process of the conducted review.

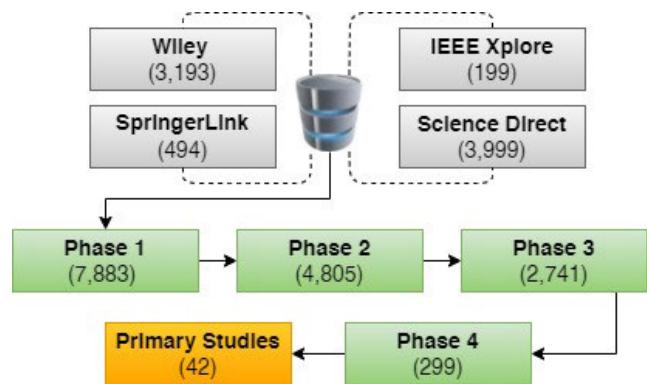


FIGURE 5. Tollgate-based primary study selection process.

TABLE 2. Main phases of paper's selection process.

Phase #	Phase Description
P1	Papers extracted through Search Terms
P2	Inclusion/exclusion based on title and abstract
P3	Inclusion/exclusion based on introduction and conclusions
P4	Inclusion/exclusion based on Skimming and Scanning of full text
P5	Total selected articles for the primary study

the quality criteria. The following sections provide the details about these activities:

1) PRIMARY STUDY SELECTION

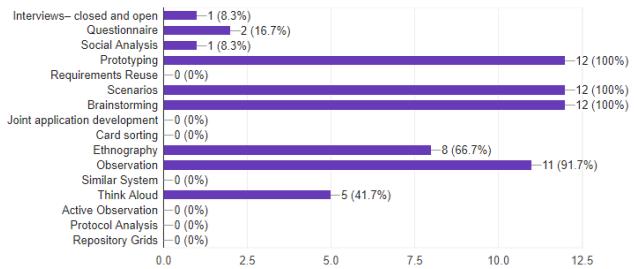
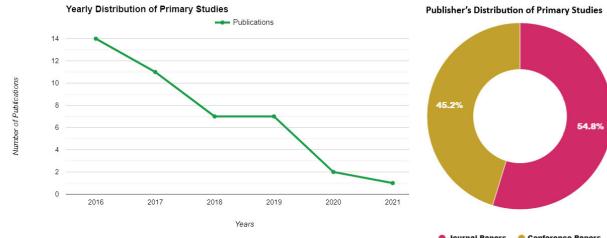
In this section, we gathered numerous research articles from targeted database repositories through the tailored search string and passed them through proper analysis process to filter out the most relevant papers.

To refine the process of primary study selection, a tollgate approach was being used that is proposed by Afzal *et al.* [25]. The employed Tollgate approach comprises of five different phases, described in Table 2.

In the first phase, a total of 7,883 articles were extracted from selected databases grounded on the search terms and keywords. In the second phase, 4,805 articles were selected on the basis of title and abstract criteria. In the third phase, 2,741 articles were selected based on the introduction and conclusion sections. In the fourth phase, skimming and scanning of articles was performed and 299 articles were

TABLE 3. The details of primary study selection process.

Database	P1	P2	P3	P4	P5	%
Wiley	3,193	2,113	941	124	15	35.71 %
IEEE Xplore	199	146	52	1	00	0.00 %
SpringerLink	494	278	128	82	08	19.04 %
Science Direct	3,999	2,268	1,620	92	19	45.23 %
Total	7,883	4,805	2,741	299	42	100 %

**FIGURE 7.** Expert's responses.**FIGURE 6.** Temporal distribution of the selected studies.

finalized. Finally, in the fifth phase, after applying the skimming and scanning on full text and removal of duplicate studies, 42 primary studies were finalized. Figure 5 illustrates the phases of primary study selection process. Moreover, Table 3 provides the details of primary study Selection.

2) DATA EXTRACTION

The articles selected (for primary study) were based on the parameters such as publication year, research methodology used, author name, and the limitations that are associated with them. The list of articles selected as primary studies is shown APPENDIX A. Moreover, to ensure the relevancy of primary studies, the formulated research questions were cross mapped with the selected articles.

3) DATA SYNTHESIS

In data synthesis phase, the research articles were being passed through the phases of tollgate approach for the purpose of synthesizing the data. Moreover, the data gathered from primary studies were evaluated with the research questions generated for the research. From total of 42 articles, 40 challenges and 18 requirements elicitation were identified.

C. REPORTING THE REVIEW

In third phase of SLR, the primary studies are evaluated with respect to the quality questions, devised to assess and maintain the quality of primary studies. This section provides the details of the temporal distribution of studies to identify the research trends. The following sections provide the details of these activities:

1) QUALITY ATTRIBUTES

To assess the quality, all the selected primary studies were reviewed and assessed (mentioned in APPENDIX B). APPENDIX B consists of quality scores of primary studies with respect to the generated quality criteria questions. The average score of each paper is greater than 50% (i.e. 2.5). Hence, this score depicts that the selected articles have satisfied the quality criteria and possesses more relevancy with the current research work.

2) TEMPORAL DISTRIBUTION OF SELECTED STUDIES

It has been observed that there is significant decrease in the number of publications after year 2019. The rapidly changing trends and new advancements in the industry demand more attention towards the quality product. Undoubtedly, quality-oriented requirements elicitation process provides a base essential for the success of a software project.

However, the 54.8% (24 out of 42) selected primary studies were published in well reputed journals, whereas 45.2% (18 out of 42) were published in conference proceedings. Figure 6 illustrates the temporal distribution of the selected primary studies.

IV. RESULTS

This section provides the results and analysis for each of the formulated research questions. Moreover, for evaluation of the obtained results, empirical assessments are also performed.

RQ1 (What Are Various Requirements Elicitation Techniques Employed by Requirements Engineers?): Requirements are being collected or elicited through the consultation of end users and stakeholders. However, for different stakeholders, single method is not enough to demonstrate the information about the problem. Moreover, it is almost impossible to use particular and generic method to elicit the requirements due to the changes in situational context during the elicitation process [15]. To explain the types of techniques, a total of 29 (out of 42) articles were targeting 18 different requirements elicitation techniques. Table 4 elaborates different requirements elicitation techniques along with their references, frequency, and percentage.

To analyze the significance of requirements elicitation techniques, the criteria of frequency having greater than 50% are categorized as important techniques, as followed by

TABLE 4. Requirements elicitation techniques.

Sr. #	Technique	Primary Study Reference	Frequency	Percentage (n = 29)
ET-1	Interviews—closed and open	[PS1-PS5], [PS10, PS11], [PS13-PS16], [PS18], [PS20-PS22], [PS24, PS25], [PS27-PS32]	23	79.31 %
ET-2	Questionnaire	[PS1-PS3], [PS5, PS6], [PS10-PS16], [PS18], [PS20, PS21], [PS23-PS27], [PS32, PS33]	21	72.41 %
ET-3	Social analysis	[PS2], [PS3], [PS5, PS6], [PS10], [PS15], [PS19], [PS25], [PS28], [PS32]	10	34.48 %
ET-4	Prototyping	[PS1-PS6], [PS11-PS13], [PS15, PS16], [PS18], [PS20-PS25], [PS28, PS29]	20	68.96 %
ET-5	Requirement reuse	[PS2], [PS5], [PS10-PS16], [PS20-PS24], [PS29]	15	51.72 %
ET-6	Scenarios	[PS1], [PS3-PS6], [PS9], [PS12], [PS14-PS18], [PS20-PS25], [PS30]	19	65.51 %
ET-7	Brainstorming	[PS1-PS6], [PS9], [PS11-PS16], [PS18], [PS20-PS25], [PS27]	20	68.96 %
ET-8	Joint application development	[PS2], [PS4-PS6], [PS9], [PS11-PS14]	9	31.03 %
ET-9	Card sorting	[PS1, PS2], [PS4], [PS8], [PS15], [PS18], [PS20-PS25], [PS27]	13	44.82 %
ET-10	Ethnography	[PS1, PS2], [PS4-PS6], [PS9-PS13], [PS15-PS18], [PS20-PS25], [PS27-PS29]	21	72.41 %
ET-11	Observation	[PS1-PS6], [PS9], [PS11-PS16], [PS20-PS25], [PS28]	20	68.96 %
ET-12	Similar System	[PS3-PS6], [PS9], [PS12], [PS14-PS16], [PS20-PS25], [PS29]	16	55.17 %
ET-13	Think Aloud	[PS1, PS2], [PS4-PS8], [PS10-PS13], [PS17], [PS25]	12	41.37 %
ET-14	Active Observation	[PS1-PS5], [PS7], [PS9-PS16], [PS18], [PS20-PS24]	20	68.96 %
ET-15	Protocol Analysis	[PS2, PS3], [PS10], [PS19], [PS20], [PS22], [PS24], [PS26]	8	27.58 %
ET-16	Repository Grids	[PS2], [PS4, PS5], [PS10], [PS15, PS16], [PS21]	7	24.13 %
ET-17	Social Analysis	[PS1-PS6], [PS8], [PS10-PS12], [PS15], [PS19], [PS25]	13	44.82 %
ET-18	Application Analysis	[PS4-PS6], [PS10], [PS13], [PS17]	6	20.68 %

one of the similar studies [4]. Hence, according to above-mentioned criteria, the important elicitation techniques are Interviews [ET-1], Questionnaire [ET-2], Prototyping [ET-4], and Requirements reuse [ET-5], Scenarios [ET-6], Brainstorming [ET-7], Ethnography [ET-10], and Observation [ET-11], Similar System [ET-12], Think Aloud [ET-13] and Active Observation [ET-15].

RQ1.1 (What Are Specific Techniques Used by the Requirements Engineers to Elicit the Tacit Knowledge?): The transfer of tacit knowledge is considered as the major issue during eliciting the requirements. The requirements analysts used different techniques to detect and uncover the tacit knowledge [16]. We performed an empirical study to identify the existing techniques that might be helpful in uncovering the hidden tacit knowledge. Figure 7 illustrates the obtained responses. As depicted by the expert's responses (Figure 7), all of the respondents agreed that Prototyping, Scenarios, and Brainstorming could be used to elicit the tacit requirements. However, according to the experts, ethnography and Think Aloud are also being used. Moreover, 50% of the respondents mentioned that “Storytelling” and “Storyboarding” techniques are also useful to uncover the tacit knowledge. The demographics of experts are shown in Figure 20.

RQ2 (What Are Various Challenges Which Affect Negatively on the Elicitation Process During Software Development?):

Eliciting the requirements from stakeholders is an early yet highly precarious stage in RE phase. This stage is more likely to be affected by the occurrence of error as it comprises of different important challenges that need to be handled [10]. The identification of relevant end users or stakeholders and ascertaining their actual needs are the basis of success and failure of requirements elicitation process. Due to the poor communication between stakeholder and analyst, there are more chances of occurrence of error which may result in the utilization of extra resources such as time and cost [24]. There are many other challenges as well which affect the requirements elicitation process. Hence, to find out the Requirements elicitation challenges, a total of 31 (out of 42) articles were targeting 40 different requirements elicitation challenges. APPENDIX C elaborates different requirements elicitation challenges along with their references, frequency, and percentage.

To analyze the significance of elicitation challenges, we used the criteria based on their frequency as followed by one of the similar studies [4].

TABLE 5. The significance of challenges.

Significance	Criteria	Challenges
High	Frequency > 50%	[C1], [C7], [C8], [C9], [C13], [C18], [C20], [C27], [C29], [C33], [C35]
Medium	Frequency 25% - 50%	[C2], [C5], [C6], [C12], [C15], [C23], [C24], [C25], [C26], [C28], [C30], [C32], [C36], [C38], [C39], [C40]
Low	Frequency < 25%	[C3], [C4], [C10], [C11], [C14], [C16], [C17], [C19], [C21], [C22], [C31], [C34], [C37]

TABLE 6. The expert's demographics.

#	Country	Position	Experience (Years)	
			Academic	Industrial
1-	Pakistan	Project Manager	7	5
2-	Pakistan	Project Manager	5	3
3-	USA	Requirement Engineer	4	5
4-	Germany	Requirement Engineer	4	7
5-	Germany	Requirement Engineer	3	4

The challenges having frequency percentage greater than 50% are considered as high significant challenges. That in this case are Poor Communication [C1], identification of relevant stakeholder [C8], ambiguities among stakeholders [C9], Unawareness of need [C10], Vague information / implicit knowledge [C14], Experts experience & technical know-how [C19], Insufficient levels of detail of requirements (vague requirements) [C28], Communication Issues [C31], Knowledge is tacit [C33], and Knowledge exchange capability [C37]. Table 5 illustrates the high, medium, and low significance of challenges.

RQ2.1 (What Is Categorization and Prioritization of Various Challenges That Affect the Elicitation Process?): For the categorization and prioritization of identified challenges, we used expert judgment method. We approached two Project Managers and three Requirements Engineers possessing strong industrial and academic background. We categorized and prioritized the challenges on the basis of mutually agreed mapping from each targeted practitioner. To gather and analyze the feedback, we conducted total 5 meetings each consisting of approximately 1 hour. Table 6 represents the information demographics of targeted expert.

A. CATEGORIZATION OF CHALLENGES

All the challenges identified from literature are categorized into four main categories: (i) Communication, (ii) Organizational, (iii) Analyst, (iv) Technical and

Stakeholder (COATS). For this categorization, we selected the descriptive categories from Zowghi *et al.* [38] and mapped the associated challenges. Figure 8 (APPENDIX F) illustrates the categorization of all the identified challenges.

B. PRIORITIZATION OF CHALLENGES

To prioritize the significance of elicitation challenges, we used the criteria based on their frequency as followed by the study [4]. Challenges having frequency percentage greater than 50% are considered as high significant challenges. In this case, Poor Communication [C1], identification of relevant stakeholder [C8], ambiguities among stakeholders [C9], Unawareness of need [C10], Vague information / implicit knowledge [C14], Experts experience & technical know-how [C19], Insufficient levels of detail of requirements (vague requirements) [C28], Communication Issues [C31], Knowledge is tacit [C33], and Knowledge exchange capability [C37]. Challenges having frequency percentage between 25% and 50% are considered as medium significant challenges. However, challenges having frequency percentage less than 25% are considered as low significant challenges. After removing the most likely duplication, identified challenges having high and medium significance are prioritized among 5 main categories. Table 7 illustrates the prioritization of challenges.

1) EMPIRICAL EVALUATION OF CHALLENGES

This section specifies the details concerning the design and implementation of performed survey analysis through industry practitioners. Furthermore, it includes the investigation against the prioritized requirements elicitation challenges. After that a contrast has been drawn among the challenges from literature and industry.

C. SURVEY DESIGN

To procure the industrial perspective against the top 15 critical challenges identified from literature, a survey questionnaire was premeditated and developed.

Requirements Engineers, Project Managers and Developers were being targeted as primary respondents. Moreover, to achieve the legitimacy and validity of results, all the respondents were targeted who belong to multinational organizations from all over the globe. To analyze the criticality of challenges, a 5-Point Likert scale (Strongly agree, Agree, Neutral, Disagree, Strongly disagree) was used. Figure 9 provides the demographics of respondents from the survey. After obtaining the responses from the targeted audience were converted into the percentages, and appropriate data analysis tests were performed.

D. DATA ANALYSIS

For analysis of data, we performed Levene's test, T-test, and Spearman Correlation test to validate the result's authenticity and legitimacy [44].

TABLE 7. Prioritization of challenges.

Category	Challenge/s	Frequency	Priority	Critical Challenge (CC) ID
Communication	[C1] Poor Communication	25	1	CC1
	[C20] Lack of Confidence	19	6	CC8
	[C28] Poor presentation skills	10	11	CC16
	[C29] Knowledge is tacit	23	2	CC2
	[C30] Poor decision-making capacity	12	9	CC13
	[C32] Poor negotiation capacity	10	11	CC17
	[C33] Poor knowledge exchange capability	22	3	CC4
	[C39] Cultural and language barrier	11	10	CC14
Analyst	[C18] Experts experience & technical know-how	20	5	CC7
	[C23] Appropriate selection of technique	11	10	CC15
	[C24] Lack of time/cost	9	12	CC20
Stakeholder	[C6] Intra-group conflicts	9	12	CC21
	[C7] Identification of relevant stakeholder	22	3	CC5
	[C8] Ambiguities among stakeholders	23	2	CC3
	[C9] Unawareness of need	21	4	CC6
	[C12] Unrealistic demands of stakeholders	9	12	CC22
	[C15] Lack of technical knowledge	9	12	CC23
Technical	[C13] Vague information / implicit knowledge	19	6	CC9
	[C25] Scope not sufficiently defined at early stage	9	12	CC24
	[C26] Change in requirements with time	10	11	CC18
	[C27] Insufficient levels of detail of requirements	18	7	CC11
Organizational	[C2] Management and political rules	13	8	CC12
	[C5] Diverse Cultural Background	8	13	CC26
	[C35] Institutional politics and bureaucracy	19	6	CC10
	[C36] Geographical Distribution of Stakeholders and Analysts	10	11	CC19
	[C38] Organizational strategies	9	12	CC25

TABLE 8. The results of levene's test.

SUMMARY						
Groups	Count	Sum	Average	Variance		
70.71	6	335.69	55.9483333	313.186537		
71.42	6	242.83	40.4716667	88.4217767		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	718.581633	1	718.581633	3.57851971	0.08781605	4.96460274
Within Groups	2008.04157	10	200.804157			
Total	2726.6232	11				

1) LEVENE'S TEST

To ensure the consistency of variance between the outcome of empirical study and SLR, we applied Levene's test. Table 8 presents the resultant values of percentages and variance of data.

2) T-TEST

To analyze the mean differences between Empirical Study and SLR, we applied t-test. The outcome of t-test was $t = -1.51$ and $p = 0.04$, which clearly indicates that there

is no prominent difference between the outcome of SLR and the performed empirical study. Top 15 challenges having critical and moderate significance are being compared. Table 11 describes the comparison of challenges from industry and literature.

3) SPERSMAN TEST

To evaluate the importance of differences between the ranks collected from SLR and Empirical Study, we applied spearman correlation test.

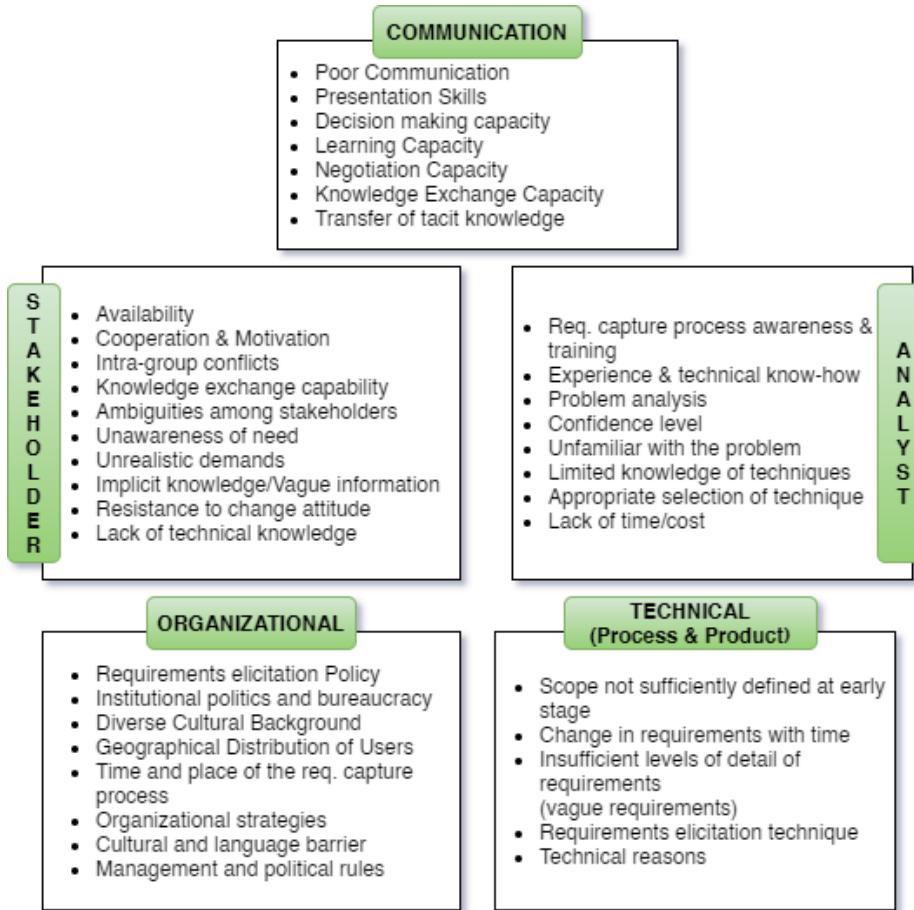


FIGURE 8. Categorization of challenges.

Notice that in Spearman correlation test, if the value of coefficient is near or close to +1.0, then it represents the positive correlation. Notice that if the value of coefficient is closer to -1.0, then it represents the negative correlation. In the conducted study, the Spearman coefficient was 0.21523651, which clearly indicates the strong positive correlation between the rankings that are obtained from SLR and Empirical Study results. Table 9 represents the percentage and ranks of data obtained from SLR and Empirical Study.

RQ3 (What Are Various Challenges That Negatively Affect by COVID-19 Pandemic During Requirements Elicitation?): COVID-19 pandemic has affected all of the daily routine activities and evoked an era of agility [14]. In the conducted survey, we asked the practitioners whether the requirements elicitation process in in-house software development is negatively affected due to COVID-19 pandemic or not. 72% of the practitioners agreed with the statement that this pandemic era has affected the process of requirements elicitation as it requires more human to human interaction. Figure 10 illustrates the division of percentage of respondents from the conducted empirical study.

Figure 11 portrays the comparison of impact of critical challenges before and during COVID-19 pandemic.

Moreover, we calculated the percentage of impact on each challenge by subtracting the before COVID-19 percentage from the percentage obtained during COVID-19. Table 10 illustrates the percentages and overall impact of before and during pandemic situation.

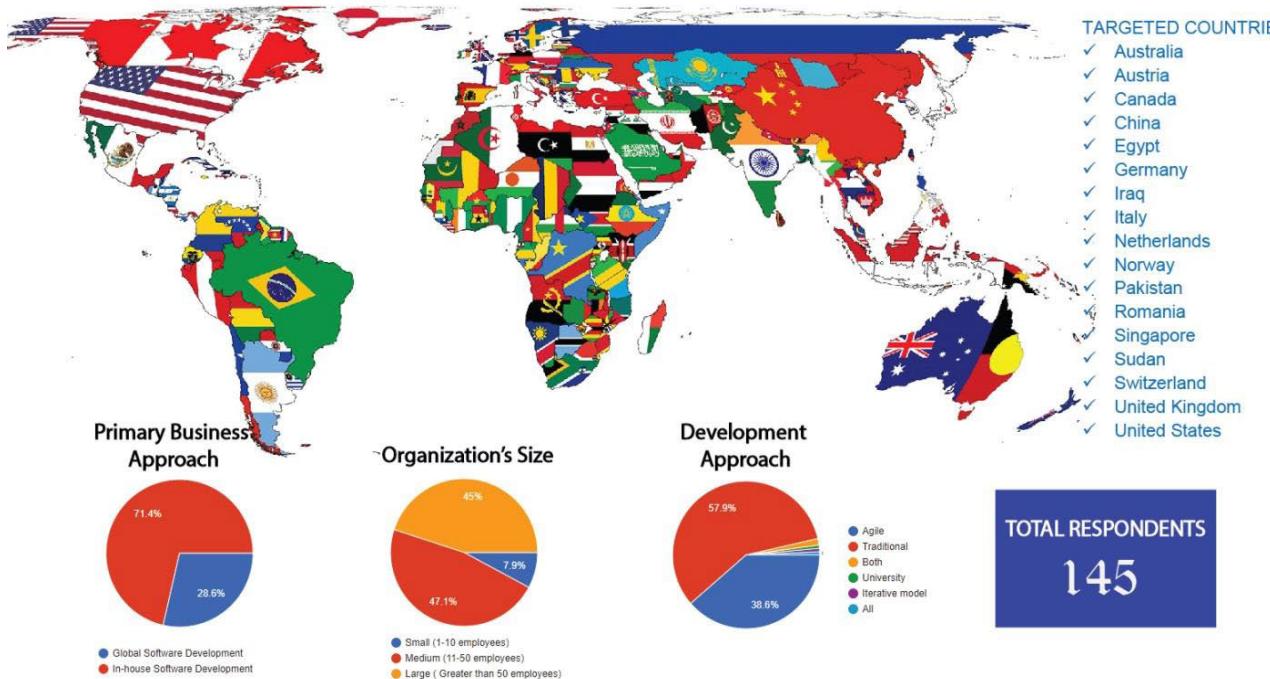
Moreover, there are some additional challenges that are being faced by the practitioners during the COVID-19 pandemic situation. It is to be noticed that these challenges are not defined or highlighted in the literature. The identified challenges include *team size*, *response delay*, *work pressure*, *multiple vendors' involvement*, and *communication infrastructure*.

E. IC01- TEAM SIZE

Group size is an important challenge when working remotely. Smaller groups can complete the task more efficiently and effectively as they need to communicate more frequently.

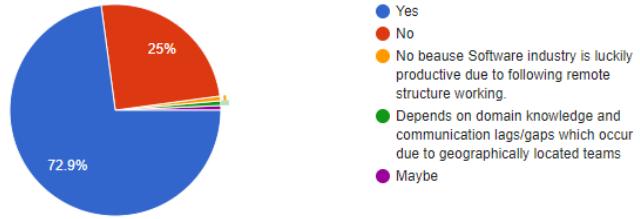
F. IC02- RESPONSE DELAY

Due to the restrictions in pandemic scenario, all work relied on online collaborative tools. Analysts and stakeholders communicate through online conferencing tools. Hence, the delay in response from analyst or stakeholder results in the

**FIGURE 9.** Demographics of respondents.**TABLE 9.** The results of SLR and empirical study.

Challenge/s	SLR %age	SLR Rank	Survey %age (n=145)	Survey Rank
Poor Communication	80.64	1	70.71	2
Knowledge is tacit	74.19	2	51.42	7
Ambiguities among stakeholders	74.19	2	57.14	5
Knowledge exchange capability	70.96	3	45.71	5
Identification of relevant stakeholder	70.96	3	43.57	10
Unawareness of need	67.74	4	90.71	1
Experts experience & technical know-how	64.51	5	47.14	8
Lack of Confidence	61.29	6	58.57	4
Vague information / implicit knowledge	61.29	6	64.28	3
Institutional politics and bureaucracy	61.29	6	44.28	9
Insufficient levels of detail of requirements	58.06	7	72.41	4
Management and political rules	39.39	8	59.31	6
Decision making capacity	38.70	9	47.58	10
Cultural and language barrier	35.48	10	50.34	9
Appropriate selection of technique	35.48	10	51.03	7

formation of ambiguities as all the analysts or stakeholders are collaborating from different surroundings.

**FIGURE 10.** Division of respondents.

G. IC03- WORK PRESSURE

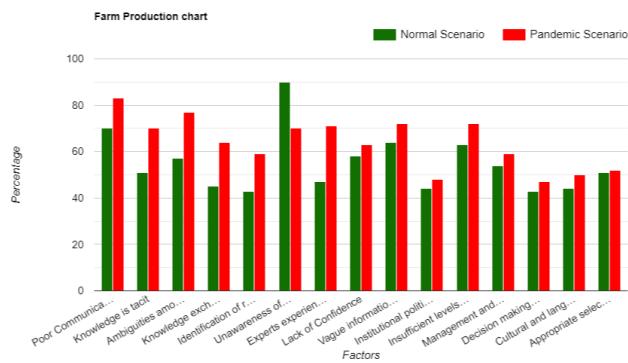
In the pandemic scenario, the work pressure has increased due to rapid increase in demand of collaborative software systems as each activity is shifted to online. The exponential increase in demand resulted in the increase of work pressure and hence the analysts lack in having enough time to properly gather the requirements from stakeholders. Moreover, the stakeholders need the systems to be built as soon as possible so that less time might get wasted.

H. IC04- MULTIPLE VENDORS INVOLVEMENT

Involving the multiple vendors during the pandemic times is challenging, as it needs much time to find, manage and communicate with them. It is a matter of fact that communication is badly affected in pandemic scenario and involving multiple vendors in a project means communicating with more channels. More communication channels may result in the poor requirements elicitation process. Furthermore, multiple vendors might have multiple perspectives, and dealing with

TABLE 10. Impact of before and during pandemic situation.

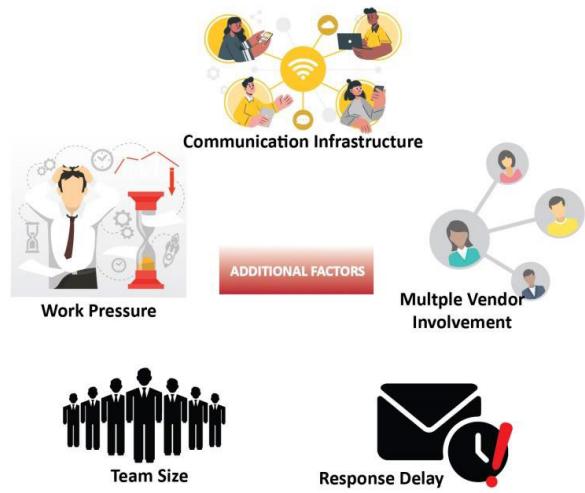
Challenges	Percentages		
	Before COVID	During COVID	Impact Difference
Poor Communication	70.71	83.57	12.86
Knowledge is tacit	51.42	70.00	18.58
Ambiguities among stakeholders	57.14	77.14	20
Knowledge exchange capability	45.71	64.28	18.57
Identification of relevant stakeholder	43.57	59.28	15.71
Unawareness of need	90.71	70.71	-20
Experts experience & technical know-how	47.14	71.42	24.28
Lack of Confidence	58.57	63.57	5
Vague information / implicit knowledge	64.28	72.85	8.57
Institutional politics and bureaucracy	44.28	48.57	4.29
Insufficient levels of detail of requirements	63.44	72.41	8.97
Management and political rules	54.48	59.31	4.83
Decision making capacity	43.75	47.58	3.83
Cultural and language barrier	44.13	50.34	6.21
Appropriate selection of technique	51.72	57.24	5.52

**FIGURE 11.** Comparison of before and during Pandemic.

many perspectives where communication is not up to the mark might result in the failure of project.

I. IC05- COMMUNICATION INFRASTRUCTURE

It is a matter of fact that communication is badly affected due to the restrictions in COVID-19 scenario. The communication channels used by the analysts and stakeholders are mostly the collaborative tools. The analysts know the usage of these channels but the stakeholders being the lay persons in industry do not know how to efficiently use these tools unless

**FIGURE 12.** Five additional challenges.

they are being properly trained for them. This lack of training might create the communication gap between the analyst and stakeholder.

Figure 12 illustrates the five additional challenges being identified through Empirical Study.

RQ4 (How the Effect of Identified Challenges During Requirements Elicitation Process Can be Mitigated in COVID-19 Pandemic Context?): Elicitation process needs to be error prone so that the requirements gathered by analyst are accurate enough to meet the stakeholder's goal [16]. The analysts need to identify the relevant stakeholder. Identification of relevant stakeholder is very crucial as they will be the primary source of information and they possess the actual needs and goals of system to be built [18]. After that, the analysts need to capture and document the goals and objectives of stakeholders at an early stage. The analyst needs to be a good listener and keen observer. The analyst's assumption might work as a poison to the system, so analysts need to confirm the requirements from stakeholders by providing the prototypes [20].

Requirements Elicitation process is human-centered process, so it exclusively depends on the communication between the analyst and stakeholder. However, in pandemic scenario, the face-to-face communication has been affected badly [29]. Therefore, in the conducted empirical study, we asked the practitioners to provide the guidelines they are followed to mitigate this effect.

Following are some of the practices/guidelines provided by the practitioners:

- Select and create right communication channel such as *MS Teams, Skype*.
- Perform appropriate inspection time to time while eliminating the hurdles.
- Target each module of system to be built as a goal and define clear timelines.

- iv. Involve the stakeholders more frequent than usual to avoid miscommunication.
- v. *Quick Prototyping* could be used to provide the visuals among stakeholders and analysts to avoid ambiguity.
- vi. Make sure the clarification in communication at both stakeholders and analysts ends.
- vii. Avoid involving too many resources in the process of communication.
- viii. The communication with stakeholders should be fluent and fast.
- ix. Agile workflow management tools such as *Asana*, *Notion* and *Mondays* could be used to manage the tasks.
- x. Team collaboration amongst cross departmental teams should be enhanced in order to ensure that the requirements are elicited through proper process.
- xi. Each step of development should be properly documented and tracked.
- xii. Professional training should be provided to the team to work online.
- xiii. Develop strategies/processes to counter challenges faced during working.
- xiv. Soft skills of both stakeholders and analysts must be enhanced and training should be provided by company.

V. DISCUSSIONS

The aim of current research work is to identify requirements elicitation techniques and challenges. Moreover, to identify the communication issues faced during COVID-19 pandemic. For this purpose, we performed a SLR to identify the challenges and to support, we performed an empirical study. The practitioners were asked the questions to verify the facts that were found from the literature. In this section, the findings of formulated research questions are discussed.

Regarding **RQ1**, we have identified different techniques to be used for elicitation process with the help of SLR. We have found a total of 42 articles from which 29 targeting 18 different requirements elicitation techniques. After performing the frequency analysis, we analyzed the significance of elicitation techniques. The important elicitation techniques are Interviews - Open and closed, Questionnaire that is easily manageable and may target large number of audiences. Prototyping, easily understandable as it is a visual mockup of the product that is intended to be built. Moreover, it could be used to remove the ambiguities among the analysts and stakeholders. Other important techniques are requirement reuse, brainstorming, ethnography, observation, similar system and active observation.

Regarding **RQ1. 1**, we performed an empirical study to identify the specific techniques that could be used to elicit the tacit requirements. We targeted 12 experts from industry for this purpose. All of the respondents agreed that Prototyping, Scenarios, and Brainstorming could be used to elicit the tacit requirements. 91% of respondents voted for Observation. However, according to experts, ethnography and Think Aloud are also being used. Moreover, 50% of the respondents said

that “Storytelling” and “Storyboarding” techniques are also useful to uncover the tacit knowledge

Regarding **RQ2**, we performed the SLR to identify the challenges. A total of 42 articles from which 31 were targeting 40 different requirements elicitation challenges.

To analyze the significance of elicitation challenges, we used the criteria based on their frequency as followed by one of the similar studies [4]. The challenges having frequency percentage greater than 50% are considered as high significant challenges. That in this case are Poor Communication [F1], identification of relevant stakeholder [F8], ambiguities among stakeholders [F9], Unawareness of need [F10], Vague information / implicit knowledge [F14], Experts experience & technical know-how [F19], Insufficient levels of detail of requirements (vague requirements) [F28], Communication Issues [F31], Knowledge is tacit [F33], and Knowledge exchange capability [F37]. The division made it easy to differentiate the challenges and helped us in the prioritization.

Regarding **RQ2.1**, we have categorized the challenges into five main categories Communication, Organizational, Analyst, Technical and Stakeholder (COATS). After removing the most likely duplication, identified challenges having high and medium significance are prioritized.

Regarding the **RQ3**, we have identified that software elicitation process is affected negatively due to pandemic restrictions. 72% of the practitioners agreed with the statement that this pandemic era has affected the process of requirements elicitation as it requires more human to human interaction. Moreover, we have identified five additional challenges that influenced the requirements elicitation process during pandemic time. The identified challenges are *team size*, *response delay*, *work pressure*, *multiple vendors' involvement*, and *communication infrastructure*.

Regarding **RQ4**, we asked the industrial practitioners to provide the practices/guidelines they followed to mitigate the effect of challenges that are highlighted during Pandemic time.

The suggested practices allow the practitioners to further investigate and propose the appropriate strategies to help the practitioners in pandemic era.

VI. PROPOSED CONCEPTUAL MODEL

Based on the outcome of conducted empirical study and performed SLR, we propose a conceptual model to gather the unambiguous requirements in the form of verified tacit knowledge. To accomplish this, first of all, we gathered the challenges that affect the requirements elicitation process. With the consultation of industrial practitioners, we categorized and prioritized the requirements elicitation challenges. The prioritized challenges were then analyzed by the practitioners in the context of normal and pandemic scenario. After that the practitioners were asked to provide the guidelines to overcome the effect of challenges during the COVID-19 pandemic scene.

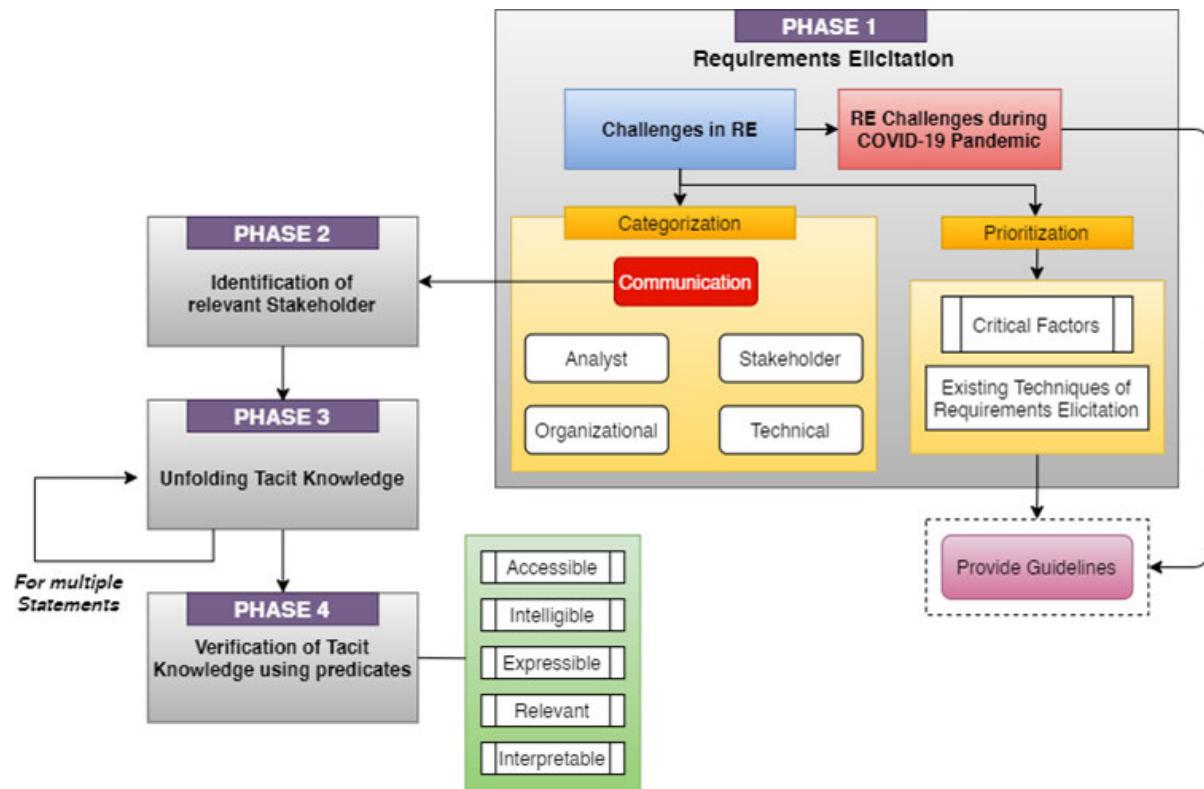


FIGURE 13. High-level view of proposed conceptual model.

In phase 2, we identify the relevant stakeholder(s) from whom the analysts will communicate to gather the information regarding the system to be built. Phase 3 consists of the steps to unfold the ambiguous statement(s), considering transfer of tacit knowledge in communication as the most highlighted challenge. Similarly, in phase 4 of the proposed model, the obtained tacit/unfolded statements were verified using the predicates *Accessible*, *Intelligible*, *Expressible*, *Relevant*, and *Interpretable*. Figure 13 illustrates the main phases of proposed conceptual model.

A. PHASE 2: IDENTIFICATION OF RELEVANT STAKEHOLDER

In phase 2 of proposed conceptual model, different activities are performed to identify the relevant stakeholders. In the beginning, we have a pool consisting of both active and passive stakeholders. The output of phase 2 is to identify the active stakeholders and neglect the passive stakeholders (i.e., their roles are not important for requirements elicitation of a certain system). The first and foremost step is to call a general meeting and involve the pool of all possible stakeholders. Next, state them the goal or aim of project that needs to be achieved, provide them a set of role identification criterion [35], [36]. After that we asked them to individually brainstorm and note down the roles of stakeholders that might be important to achieve the certain goal. Figure 19

(APPENDIX E) depicts the sample template of role identification's questionnaire.

Afterwards, we make the pairs of stakeholders randomly and allow them to again brainstorm and discuss roles in pairs. The role identification questionnaire [35], [36] is provided and asked them to rank the selected roles individually according to the provided criterion with justification. After pair brainstorming, group brainstorming is performed. Each pair is asked to discuss or present their results along with the provided rankings. At the end, the roles having high ranking are considered as the active stakeholders that may help to achieve the certain goal.

Figure 20 (APPENDIX E) presents the sample guideline questions. Moreover, Figure 14 describes the process of identification relevant stakeholder.

B. PHASE 3: UNFOLDING TACIT KNOWLEDGE

Phase 3 is regarded as the main phase of proposed conceptual model. When using expert judgment as a knowledge repository to gather the requirements, the ambiguous statements from expert stakeholders are to be analyzed. Whenever a stakeholder expresses the element of information, ambiguity occurs as the meaning associated with that element of information may differ from the meaning intended by the stakeholder. This ambiguity indicates the presence of tacit knowledge [23].

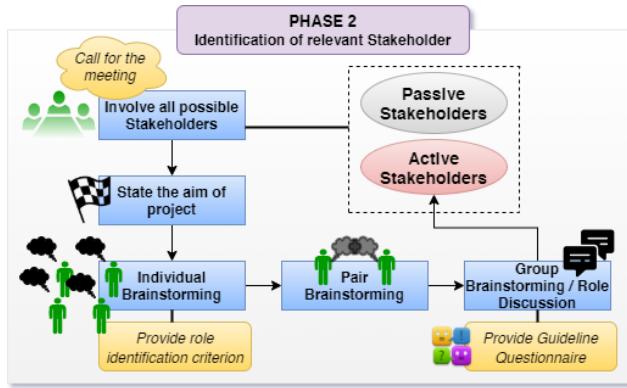


FIGURE 14. PHASE 2 - identification of relevant stakeholder.

For example, Ferrari *et al.* [43] stated following example of ambiguity. “One of our customers is a bio-medical engineer and wants to develop a system that patients can use to measure their blood pressure. The system shall include a mobile application, which sends the data about the blood pressure to the general practice doctor. When asked how blood pressure is currently measured, the customer said: There is this device. Customer uses the device on regular basis but didn’t know its name, specifications, and details. The analyst correctly understood that a specific device is used. Since, from the implementation point of view, the analyst thought that a precise name, or brand, for the device was needed, to develop an interface between the mobile phone and the device. After asking, it was clarified that the bio-medical engineer did not know the name of the device (i.e., blood pressure monitor).”

To further elaborate the term “Ambiguity”, another example specified in study [43] is as follows:

“One of our customers wants to develop a mobile application that monitors the use that she makes of her mobile phone. She said: Maybe the system could give me also some recommendations. The analyst thought that the term recommendations could have two acceptable meanings: (a) negative recommendations on applications and mobile features that she should not use (b) positive recommendations on applications that could be downloaded and mobile features that 59 could be used. After clarification, the first meaning resulted correct.”

So, considering the ambiguous statement(s) as an input, the first step is to generate the associated goal with that statement and confirm that goal from the stakeholder. Second step is to brainstorm and raise the relevant question/s or query/s to the identified stakeholders. Afterwards, gather all the perspectives from the stakeholders. Each stakeholder might have multiple perspectives regarding a single query.

After getting the perspectives, evaluate the pros and cons of each perspective respectively and ask the consequence questions if need. The analyst could argue against the perspective and stakeholder could defend the argument using examples. This process of argumentation and exemplification is known as internalization. The analyst(s) could use the techniques

TABLE 11. Criteria and corresponding query.

Criteria	Query
Design	Please rate the "Design" of proposed conceptual model.
Readability	Are the components and labeling of proposed conceptual model Readable?
Relevancy of Components	Do all the phases of proposed model contain relevant components?
Logical Flow	The relationships and flows between the phases are logical?
Understandability	Does the proposed conceptual model is easy to understand for a person having average IQ level?
Correctness	Did the labels of phases correctly written?
Practicality	Does the proposed conceptual model is acceptable by Project managers/Software Requirements Engineers?
Completeness	Does the proposed conceptual model contain enough details for understandability?
	Does the information we presented in different phases/components sufficient?

such as “Prototyping” [45], [46], and “Storyboarding” [47] to affirm the perspectives when needed. The process continues until the analysts get the positives and negatives of each perspective. Keeping in mind the pros and cons, the perspectives is prioritized accordingly. Moreover, the perspectives having high priority are then compared to the associated goal. Notice that the perspective possessing most relevancies with the associated goal is considered as the unfolded statement or unfolded tacit knowledge from initial ambiguous statement. Figure 15 shows the process of the unfolding tacit knowledge.

C. PHASE 4: VERIFICATION OF TACIT KNOWLEDGE USING PREDICATES

The quality of unfolded tacit statement(s) obtained from the output of phase 3 is verified in this phase using the five predicates [16], [18]. Hence, the sentence would be:

$$\text{Tacit Knowledge } (S) = \text{Accessible} \wedge \text{Intelligible} \wedge \text{Interpretable} \wedge \text{Expressible} \wedge \text{Relevant}$$

After applying the quality criteria of “five” predicates, the quality of unfolded tacit statements is being analyzed by creating the quality review matrix. Assign scores to the sentence(s) out of 1 with respect to each predicate. Hence, the total score of each sentence depicts the attained quality. However, the process of verification of statements is shown in Figure 16.

TABLE 12. Primary study references along with their Journal/conference and publication year.

S.no	Reference	Journal / Conference	Year
PS1	R. Kasauli, E. Knauss, J. Horkoff, G. Liebel, and F. G. O. Neto, "Requirements Engineering Challenges and Practices in Large-Scale Agile System Development", vol. 172.	Journal of Systems and Software	2021
PS2	H. Dar, M. L. Ikramullah, H. Ashraf, M. Rizwan, T. Amjad, and B. Shahzad, "A Systematic Study on Software Requirements Elicitation Techniques and its Challenges in Mobile Application Development", vol. 6, pp. 63859–63867.	IEEE Access Journal	2018
PS3	H. M. Ferreira, A. O. Carvalho, E. C. Dias, R. A. Dias Kosloski, R. Á. Paldés, and E. O. Costa, "Design Thinking: Challenges for Software Requirements Elicitation", vol. 10, no. 12, 371.	Information Journal	2019
PS4	A. Ferrari, P. Spoletini, and G. Stefania, "Ambiguity and Tacit Knowledge in Requirements Elicitation Interviews", vol. 21, pp. 333–355.	Requirements Engineering Journal	2016
PS5	L. Wong, and D. Mauricio, "New Factors that affect the Activities of the Requirements Elicitation Process", vol. 13, pp. 1992–2015.	Journal of Engineering Science and Technology	2018
PS6	I. K. Raharjana, D. Siahaan, and C. Faticahah, "User Story Extraction from Online News for Software Requirements Elicitation: A Conceptual Model", pp. 342–347.	16th International Joint Conference on Computer Science and Software Engineering (JCSSE)	2019
PS7	U. Rafiq, S. S. Bajwa, X. Wang, and I. Lunesu, "Requirements Elicitation Techniques Applied in Software Startups", pp. 141–144.	43rd Euromicro Conference on Software Engineering and Advanced Applications (SEAA)	2017
PS8	F. Anwar, and R. Razali "Stakeholders Selection Model for Software Requirements Elicitation", vol. 13, pp. 726–738.	American Journal of Applied Sciences	2016
PS9	M. Bano, D. Zowghi, A. Ferrari, P. Spoletini, and B. Donati, "Teaching Requirements Elicitation Interviews: An Empirical Study of Learning from Mistakes", vol. 24(3), pp. 259–289.	Requirements Engineering Journal	2019
PS10	J. Vijayan, G. Raju, and M. Joseph, "Collaborative Requirements Elicitation using Elicitation Tool for Small Projects", pp. 340–344.	International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES)	2016
PS11	Matilde B. Jensen, Christer W. Elverum, and M. Steinert, "Eliciting Unknown Unknowns with Prototypes: Introducing Prototrials and Prototrial-Driven Cultures", vol. 49, 2017, pp. 1–31.	Design Studies journal	2017
PS12	M. Bano, M. Bano, D. Zowghi, A. Ferrari, P. Spoletini and B. Donati, "Learning from Mistakes: An Empirical Study of Elicitation Interviews Performed by Novices", pp. 182–193.	26th International Requirements Engineering Conference (RE)	2018
PS13	C. Burnay, "Are Stakeholders the Only Source of Information for Requirements Engineers? Toward a Taxonomy of Elicitation Information Sources", vol. 3, no. 8, pp. 29.	ACM Transaction Management Information System	2016
PS14	S. Besrour, L. B. A. Rahim, and P. D. D. Dominic, "A Quantitative Study to Identify Critical Requirement Engineering Challenges in the context of Small and Medium Software Enterprise", pp. 606–610.	3rd International Conference on Computer and Information Sciences (ICCOINS)	2016
PS15	Hanan Al-Zawahreh and Khaled Almakadmeh, "Procedural Model of Requirements Elicitation Techniques", no. 65, pp. 1–6.	International Conference on Intelligent Information Processing, Security and Advanced Communication IPAC Association for Computing Machinery	2016
PS16	I. Inayat, S. S. Salim, S. Marczak, M. Daneva, and S. Shamshirband, "A Systematic Literature Review on Agile Requirements Engineering Practices and Challenges", vol. 51, pp. 915–929.	Journal of Computers in Human Behavior	2016
PS17	E. Schön, D. Winter, M. J. Escalona, "Key Challenges in Agile Requirements Engineering", vol. 283, pp. 37–51.	International Conference on Agile Software Development	2017
PS18	P. Mohagheghi, and M. E. Aparicio, "An Industry Experience Report on Managing Product Quality Requirements in a Large Organization", vol. 88, pp. 96–109.	Information and Software Technology	2017

TABLE 12. (Continued.) Primary study references along with their Journal/conference and publication year.

PS19	R. Kasauli, G. Liebel, E. Knauss, S. Gopakumar, and B. Kanagwa, "Requirements Engineering Challenges in Large-Scale Agile System Development", pp. 352–361.	IEEE 25th International Requirements Engineering Conference (RE)	2017
PS20	D. Carrizo, O. Dieste, and N. Juristo, "Contextual Attributes Impacting the Effectiveness of Requirements Elicitation Techniques: Mapping Theoretical and Empirical Research", vol. 92, pp. 194–221.	Information and Software Technology Journal	2017
PS21	P. Spoletini, A. Ferrari, M. Bano, D. Zowghi, and S. Gnesi, "Interview Review: An Empirical Study on Detecting Ambiguities in Requirements Elicitation Interviews", vol. 10753.	Lecture Notes in Computer Science Journal	2018
PS22	J. Hehn, F. Uebenickel, and D. Mendez Fernandez, "DT4RE: Design Thinking for Requirements Engineering: A Tutorial on Human-Centered and Structured Requirements Elicitation", pp. 504–505.	26th International Requirements Engineering Conference (RE)	2018
PS23	A. Ferrari, P. Spoletini, B. Donati, D. Zowghi, and S. Gnesi, "Interview Review: Detecting Latent Ambiguities to Improve the Requirements Elicitation Process", pp. 400–405.	IEEE 25th International Requirements Engineering Conference (RE)	2017
PS24	A. Ferrari, P. Spoletini, and S. Gnesi, "Ambiguity Cues in Requirements Elicitation Interviews", vol. 25, pp. 56–65.	IEEE 24th International Requirements Engineering Conference (RE)	2016
PS25	T. Ambreen, N. Ikram, M. Usman, and M. Niazi, "Empirical Research in Requirements Engineering: Trends and Opportunities", vol. 23, pp. 63–95.	Requirements Engineering journal	2018
PS26	Z. Ali, M. Yaseen, and S. Ahmed, "Effective Communication as Critical Success Factor during Requirement Elicitation in Global Software Development", vol. 8, pp. 108–115.	International Journal of Computer Applications	2019
PS27	A. Wahbeh, S. Sarnikar, and O. Gayar, "A Socio-Technical-Based Process for Questionnaire Development in Requirements Elicitation via Interviews", vol. 25, pp. 295–315.	Requirements Engineering journal	2020
PS28	A. R. Asghar, A. Tabassum, S. N. Bhatti, and A. M. Jadi, "Impact and Challenges of Requirements Elicitation & Prioritization in Quality to Agile Process: Scrum as a Case Scenario", pp. 50–55.	International Conference on Communication Technologies (ComTech)	2017
PS29	S. Lane, P. O. Raghallaigh, and D. Sammon, "Requirements Gathering: The Journey", vol. 25.	Journal of Decision Systems	2016
PS30	Z. Yaseen, M. Z. Ali, Z. Halabi, A. Karrar, F. Babtain, and M. Aslam, "Success Factors during Requirements Implementation in Global Software Development: A Systematic Literature Review", vol. 8, no. 3, pp. 56–68.	International Journal of Computer Science Engineering (IJCSE)	2019
PS31	L. R. Wong, and D. Mauricio, "Qualities that the Activities of the Elicitation Process must meet to obtain a Good Requirement", pp. 2883–2912.	Journal of engineering science and technology	2019
PS-32	P. Spoletini and A. Ferrari, "Requirements Elicitation: A Look at the Future Through the Lenses of the Past", pp. 476–477.	IEEE 25th International Requirements Engineering Conference (RE)	2017
PS33	F. Adikara, B. Hendradjaya, and B. Sitohang, "Organization Goal-Oriented Requirements Elicitation Process to Enhance Information System", vol. 6, pp. 3188–3195.	International Journal of Electrical and Computer Engineering (IJECE)	2016
PS34	N. L. Atukorala, C. K. Chang and K. Oyama, "Situation-Oriented Requirements Elicitation", pp. 233–238.	IEEE 40th Annual Computer Software and Applications Conference (COMPSAC)	2016
PS35	A. Aldave, J. M. Vara, D. Granada, and E. Marcos, "Leveraging Creativity in Requirements Elicitation within Agile Software Development: A Systematic Literature Review", vol. 157, 110396.	Journal of Systems and Software	2019
PS36	M. Naeem, R. Ashraf, N. Ali, M. Ahmad, and M. A. Habib, "Bottom up Approach for Better Requirements Elicitation", no. 60, pp. 1–4.	International Conference on Future Networks and Distributed Systems, ICFNDS	2017

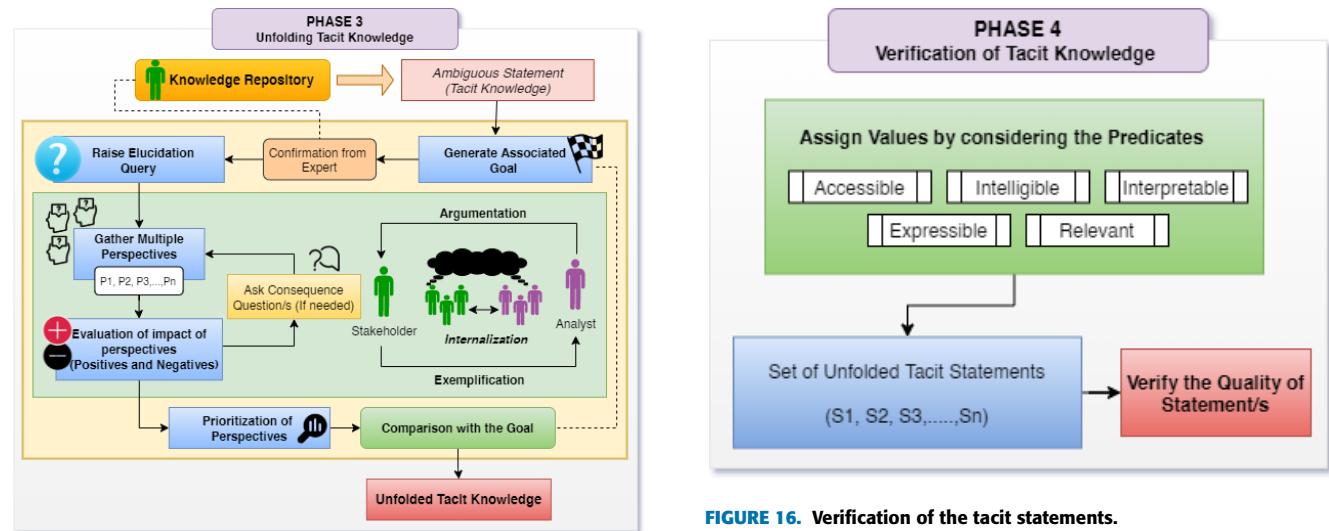
VII. VALIDATION OF PROPOSED CONCEPTUAL MODEL

This section focuses on validation of the proposed conceptual model. To validate the proposed model, we adopted two different approaches: (i) Expert's judgment/opinion, which includes initial internal expert's opinion from academia, and

(ii) Expert's validation from industry. Initially, the industrial practitioners reviewed the proposed conceptual model. Considering the feedback of experts, improvements were being made. Each subsequent section contains the detailed discussion on the process of validation of proposed model.

TABLE 12. (Continued.) Primary study references along with their Journal/conference and publication year.

PS37	G. D. Angelis, A. Ferrari, S. Gnesi, and A. Polini, "Collaborative Requirements Elicitation in a European Research Project", pp. 1282–1289.	31st Annual ACM Symposium on Applied Computing, SAC '16. Association for Computing Machinery	2016
PS38	N. Ali, and R. Lai, "A method of Requirements Elicitation and Analysis for Global Software Development", vol. 29, no. 4.	Journal of Software: Evolution and Process	2016
PS39	C. Burnay, and M. Snoeck, "Trust in Requirements Elicitation: How does it build, and Why does it matter to Requirements Engineers?", pp. 1094–1100.	Proceedings of the Symposium on Applied Computing. Association for Computing Machinery	2017
PS40	K. Curcio, T. Navarro, A. Malucelli, and S. Reinehr, "Requirements Engineering: A Systematic Mapping Study in Agile Software Development", vol. 139, pp. 32–50.	Journal of Systems and Software	2016
PS41	W. Alsaqaf, M. Daneva, and R. Wieringa, "Quality Requirements Challenges in the context of Large-Scale Distributed Agile: An Empirical Study", vol. 110, pp. 39–55.	Journal of Information and Software Technology	2019
PS42	T. Alsanoosy, M. Spichkova, and J. Harland, "Cultural Influence on Requirements Engineering Activities: A Systematic Literature Review and Analysis", vol. 25, pp. 339–362.	Requirements Engineering Journal	2020

**FIGURE 15.** PHASE 3 – unfolding the tacit knowledge.

A. INITIAL INTERNAL VALIDATION

Prior getting the expert's opinion from the industrial practitioners, we performed the initial validation. First version of the proposed conceptual model was initially evaluated by the academic experts, Dr. Saif-Ur-Rehman Khan, and Dr. Javed Iqbal. The considered experts have vast experience of industry as well as academia and currently employed at COMSATS University Islamabad (CUI) as Assistant Professors. The internal validation of model is carried out by considering parameters such as readability, logical connectivity of components and technical aspects. Moreover, novelty of proposed model was the main target while evaluation. After the initial internal validation, for further enhancements, we followed the expert's validation process. The embraced process of Expert Validation is described in Figure 17.

FIGURE 16. Verification of the tacit statements.

B. EXPERT VALIDATION

To get the external feedback on proposed conceptual model, the expert validation method was employed as shown in Figure 17. First, inclusion criterions were defined to select the most appropriate practitioners/expert. The selected experts were requested to review and evaluate the proposed model according to the provided checklist. The criterion for selecting appropriate expert is as follows:

- The expert must be employed in a Large or Medium sized organization.
- The role of expert in organization must be Project Manager or Requirements Engineer or both.
- The expert must have experience of at least five years or more.

We targeted total 12 experts that meet the defined inclusion criteria. We designed a checklist questionnaire on Google forms to get the responses. Traits such as design, readability,

TABLE 13. Quality Assessment of primary studies.

S.no.	QC-1	QC-2	QC-3	QC-4	QC-5	Total
PS1	1	0.5	1	0.5	1	4
PS2	1	1	0	1	0.5	3.5
PS3	1	1	1	0	1	4
PS4	1	1	0.5	0.5	0.5	3.5
PS5	1	1	0.5	0.5	1	4
PS6	1	1	0.5	1	1	4.5
PS7	1	1	0.5	0.5	1	4
PS8	1	1	1	0.5	0.5	4
PS9	1	1	1	0	0.5	3.5
PS10	1	0.5	1	0.5	0.5	3.5
PS11	1	0.5	1	0.5	1	4
PS12	1	1	1	0	0.5	3.5
PS13	1	1	0.5	0.5	0.5	3.5
PS14	1	1	0.5	0.5	1	4
PS15	1	0.5	1	0.5	0.5	3.5
PS16	1	1	1	0	0.5	3.5
PS17	1	0.5	0.5	0.5	0.5	3
PS18	1	0.5	0.5	1	0.5	3.5
PS19	1	0.5	0	0.5	0.5	2.5
PS20	1	1	0.5	0.5	1	4
PS21	1	1	0	1	0.5	3.5
PS22	1	1	0.5	0.5	1	4
PS23	1	1	1	0	0	3
PS24	1	0.5	1	0.5	0.5	3.5
PS25	0.5	1	1	1	1	4
PS26	1	1	1	0.5	0.5	4
PS27	1	0.5	1	0.5	0.5	3.5
PS28	1	0.5	1	0	1	3.5
PS29	1	1	0.5	0.5	0	3
PS30	1	1	0.5	0	0.5	3
PS31	1	1	0.5	0.5	1	4
PS32	1	1	1	0	0.5	3.5
PS33	1	1	1	0	0	3
PS34	1	1	0	1	0.5	3.5
PS35	1	1	0	0.5	0.5	3
PS36	1	1	0	0.5	1	3.5
PS37	1	1	1	0.5	1	4.5
PS38	1	1	1	0	0.5	3.5
PS39	1	0.5	1	0.5	0.5	3.5
PS40	1	0.5	1	1	0	3.5
PS41	1	0.5	0	1	0	2.5
PS42	1	0.5	1	0.5	0.5	3.5

and relevancy of components, logical flow, understandability, correctness, practicality, and completeness were covered. Table 11 provides the criteria and its corresponding query.

Fortunately, we got positive responses from all the experts, which clearly depicts that the model we proposed has novelty and it has potential to positively contribute to the industry. The general visual demonstrations of expert's responses are

illustrated in APPENDIX D. In contrast, Figure 18 presents the expert's demographics.

VIII. RESEARCH IMPLICATIONS

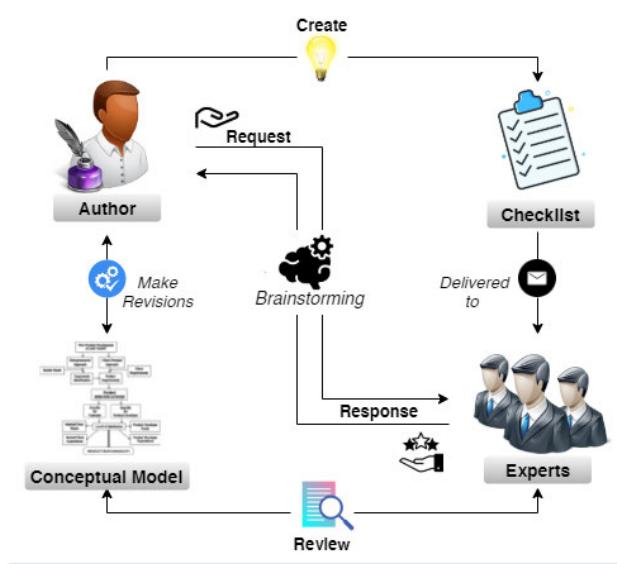
The challenges identified in current research can be used to develop and deploy a model that can mitigate their impact on the process of requirements elicitation. The basic and eventual goal is to propose the model that mitigates the effect

TABLE 14. Identified requirements elicitation challenges along with their reference and frequency.

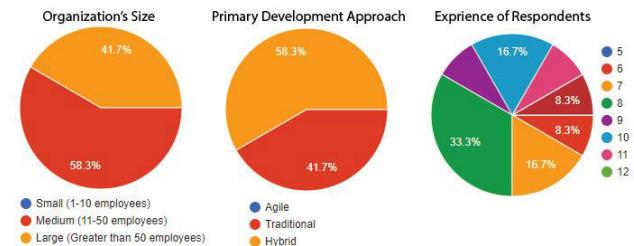
Sr. #	Challenges	Primary Study Reference	Frequency	Percentage (n = 31)
C1	Poor Communication	[PS1-PS6], [PS9-PS17], [PS20-PS25], [PS27], [PS30], [PS34], [PS36], [PS39]	25	80.64 %
C2	Management and political rules	[PS1-PS3], [PS5], [PS8], [PS11], [PS13], [PS20], [PS22], [PS35,PS36], [PS39,PS40]	13	39.39 %
C3	Lack of user's cooperation and motivation	[PS3], [PS9], [PS17], [PS24], [PS26]	5	16.12 %
C4	Stakeholders' acceptance	[PS2], [PS10], [PS15], [PS24]	4	12.90 %
C5	Diverse Cultural Background	[PS1], [PS4], [PS16], [PS17], [PS20,PS21], [PS23,PS24]	8	25.80 %
C6	Intra-group conflicts	[PS4,PS5], [PS7], [PS10,PS11], [PS15], [PS19,PS20],[PS22]	9	29.03 %
C7	Identification of relevant stakeholder	[PS3], [PS5], [PS7,PS8], [PS10,PS11], [PS15], [PS20,PS21], [PS23-27], [PS34], [PS36-PS39], [PS42]	22	70.96 %
C8	Ambiguities among stakeholders	[PS3-PS5] ,[PS7-PS17], PS20-PS25], [PS27], [PS34], [PS36], [PS39,PS40], [PS42]	23	74.19 %
C9	Unawareness of need	[PS3-PS8], [PS10-PS14], [PS16], [PS19-PS23], [PS25], [PS27], [PS34], [PS36], [PS39], [PS42]	21	67.74 %
C10	Lack of stakeholder's commitment	[PS15,PS16], [PS19,PS20], [PS25-PS27]	7	22.58 %
C11	Job position of stakeholder	[PS2],[PS7], [PS12], [PS21], [PS23]	5	16.12 %
C12	Unrealistic demands of stakeholders	[PS4,PS5], [PS7], [PS10,PS11], [PS14], [PS19], [PS21], [PS25]	9	29.03 %
C13	Vague information / implicit knowledge	[PS5],[PS7,PS8],[PS11],[PS13,PS22], [PS25],[PS28,PS29],[PS31]	19	61.29 %
C14	Resistance to change attitude	[PS8], [PS10], [PS20]	3	09.67 %
C15	Lack of technical knowledge	[PS15], [PS17], [PS19-PS22], [PS27], [PS29], [PS31]	9	29.03 %
C16	Age and Gender	[PS1], [PS3], [PS7]	3	09.67 %
C17	Requirements capture process awareness & training	[PS1-PS3], [PS5], [PS10], [PS12], [PS19]	7	22.58 %
C18	Experts experience & technical know-how	[PS1-PS4], [PS7-PS10], [PS13-PS15], [PS18-PS21], [PS23-PS25], [PS27], [PS34], [PS36], [PS39-PS40], [PS42]	20	64.51 %
C19	Lack of problem analysis	[PS3], [PS6], [PS10], [PS15], [PS19]	5	16.12 %
C20	Lack of Confidence	[PS1-PS3], [PS5], [PS7-PS9], [PS12-PS15], [PS17], [PS21], [PS23], [PS26-PS28], [PS31]	19	61.29 %
C21	Analyst is unfamiliar with the problem	[PS4], [PS8-PS11] ,[PS21]	6	19.35 %
C22	Limited knowledge of techniques	[PS4], [PS9], [PS11], [PS19], [PS21]	5	16.12 %
C23	Appropriate selection of technique	[PS3], [PS5-PS8], [PS10], [PS12],[PS16-PS18], [PS23]	11	35.48 %
C24	Lack of time/cost	[PS1-PS6], [PS9-PS11], [PS13]	9	29.03 %
C25	Scope not sufficiently defined at early stage	[PS2-PS4], [PS6], [PS8-PS10], [PS16], [PS21]	9	29.03 %
C26	Change in requirements with time	[PS1], [PS4], [PS6-PS8], [PS7,PS8], [PS10-PS13],[PS27],[PS31]	10	32.25 %
C27	Insufficient levels of details of requirements	[PS4], [PS7], [PS9-PS11], [PS13], [PS15], [PS19-PS21], [PS23-PS26], [PS28], [PS31], [PS33], [36]	18	58.06 %
C28	Poor presentation skills	[PS3], [PS5-PS9], [PS11], [PS13], [PS17], [PS21]	10	32.25 %

TABLE 14. (Continued.) Identified requirements elicitation challenges along with their reference and frequency.

C29	Knowledge is tacit	[PS3-PS5] , [4], [5], [PS7-PS11], [PS13-PS17], [PS20-PS25], [PS27], [PS34], [PS36], [PS39-PS42]	23	74.19 %
C30	Poor decision-making capacity	[PS3], [PS5-PS9], [PS11], [PS13], [PS17,PS18], [PS23], [PS29]	12	38.70 %
C31	Poor learning capacity	[PS2], [PS4-PS7], [PS11], [PS13]	7	22.58 %
C32	Poor negotiation capacity	[PS4], [PS6-PS9], [PS11-PS13], [PS15], [PS18]	10	32.25 %
C33	Poor knowledge exchange capability	[PS1-PS6], [PS8], [PS10], [PS12-PS15], [PS17], [PS21], [PS23-25], [PS27], [PS31], [PS33], [PS35]	22	70.96 %
C34	Requirement's elicitation Policy	[PS1], [PS3], [PS11]	3	09.67 %
C35	Institutional politics and bureaucracy	[PS1], [PS3], [PS5], [PS7], [PS10-PS17], [PS19], [PS21], [PS23-PS27], [PS31], [PS33], [PS38-PS40]	19	61.29 %
C36	Geographical Distribution of Stakeholders and Analysts	[PS1], [PS3-PS5], [PS7-PS9], [PS11], [PS17], [PS23]	10	32.25 %
C37	Time and place of the requirements capture process	[PS1], [PS5], [PS20]	3	09.67 %
C38	Organizational strategies	[PS2], [PS4], [PS8], [PS10-PS14], [PS20]	9	29.03 %
C39	Cultural and language barrier	[PS4], [PS6-PS9], [PS11-PS13], [PS15], [PS17], [PS21]	11	35.48 %
C40	Unavailability of Client	[PS1-PS5], [PS7-PS10], [PS13-PS15], [PS19], [PS22]	13	40.93 %

**FIGURE 17.** Expert's validation process.

of identification of relevant stakeholder and the presence of tacit knowledge in Poor Communication as the transfer of tacit knowledge in Requirements Elicitation has been the big issue. Another future direction is to develop a software tool for the proposed tacit knowledge based conceptual model which could help the practitioners to effectively elicit the tacit knowledge-based requirements.

**FIGURE 18.** The expert's demographics.

Moreover, this research highlighted the requirements elicitation related challenges critical and problematic in pandemic era in software development. Thus, it seems a great opportunity to develop such strategies or models that may help the practitioners in pandemic scenarios.

The other possible future research direction is to further analyze and validate the unfolded tacit statement by analyzing linguistically the fragments of sentences obtained as the output of phase 3 of proposed conceptual model. For example, the basic components of any sentence are the subject, the verb, and (often, but not always) the object. Hence, the validation could be performed on the tacit statements on the basis of their structure and presence of these mandatory components.

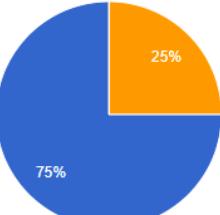
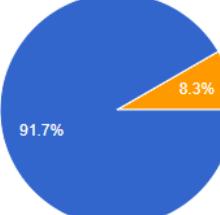
IX. THREATS TO VALIDITY

The possible validity threat related to current work is that almost all the authors of primary studies are from academia

TABLE 15. Visual demonstration of expert's responses for validation of proposed model.

Criteria	Query	Result Percentage	Description	Graphical Representation										
Design	Please rate the "Design" of proposed conceptual model	1- Excellent (41.7%) 2- Good (50%) 3- Fair (8.3%)	The aim of this question was to evaluate the design and visualization of proposed conceptual model. The experts commented that the model is visually appealing and understandable. However, 41.7% of experts gave it excellent as different graphics and colors used in model were appealing to them.	<table border="1"> <tr> <td>Very Poor</td> <td>0%</td> </tr> <tr> <td>Poor</td> <td>0%</td> </tr> <tr> <td>Fair</td> <td>8.3%</td> </tr> <tr> <td>Good</td> <td>50%</td> </tr> <tr> <td>Excellent</td> <td>41.7%</td> </tr> </table>	Very Poor	0%	Poor	0%	Fair	8.3%	Good	50%	Excellent	41.7%
Very Poor	0%													
Poor	0%													
Fair	8.3%													
Good	50%													
Excellent	41.7%													
Readability	Are the components and labeling of proposed conceptual model Readable?	1- Readable (91.7%) 2- Partially Readable (8.3%) 3- Not Readable (0%)	The aim of this question was to assess the readability of labels and components of conceptual model provided through link. 91.7 % respondents said that it is readable for them. However, 8.3% said that it can be more readable by adjusting fonts.	<table border="1"> <tr> <td>Yes</td> <td>91.7%</td> </tr> <tr> <td>No</td> <td>0%</td> </tr> <tr> <td>Maybe</td> <td>8.3%</td> </tr> </table>	Yes	91.7%	No	0%	Maybe	8.3%				
Yes	91.7%													
No	0%													
Maybe	8.3%													
Relevancy of Components	Do all the phases of proposed model contain relevant components?	1- All are relevant (66.7%) 2- Some are not relevant (33.3%) 3- Some are definitely not relevant (0%)	Basic aim for this question was to evaluate the relevancy of components of proposed model. 66% of respondents said that the phases of proposed model are relevant. However, 33% of respondents are doubtful about the relevancy.	<table border="1"> <tr> <td>All Components are relevant (Sure about relevancy)</td> <td>66.7%</td> </tr> <tr> <td>Some components might not be relevant (Doubtful about relevancy)</td> <td>33.3%</td> </tr> <tr> <td>Some components are definitely NOT relevant (Sure about non-relevancy of few components)</td> <td>0%</td> </tr> </table>	All Components are relevant (Sure about relevancy)	66.7%	Some components might not be relevant (Doubtful about relevancy)	33.3%	Some components are definitely NOT relevant (Sure about non-relevancy of few components)	0%				
All Components are relevant (Sure about relevancy)	66.7%													
Some components might not be relevant (Doubtful about relevancy)	33.3%													
Some components are definitely NOT relevant (Sure about non-relevancy of few components)	0%													
Logical Flow	The relationships and flows between the phases are logical?	1- All are logical (83.3%) 2- Some are logical (16.7%) 3- None are logical (0%)	The objective of this query was to assess the logical flow between the phases of proposed conceptual model. 83.3% of respondents said that the flow of phases seems logical to them. However, 16.7% are doubtful.	<table border="1"> <tr> <td>Yes</td> <td>83.3%</td> </tr> <tr> <td>No</td> <td>0%</td> </tr> <tr> <td>Maybe</td> <td>16.7%</td> </tr> </table>	Yes	83.3%	No	0%	Maybe	16.7%				
Yes	83.3%													
No	0%													
Maybe	16.7%													

TABLE 15. (Continued.) Visual demonstration of expert's responses for validation of proposed model.

Underunderstandingability	Does the proposed conceptual model is easy to understand for a person having average IQ level?	<p>1- Easy to understand (75%) 2- Need some explanation (25%) 3- Need Detailed Explanation (0%)</p>	<p>Basic aim of this query was to assess the understandability level of proposed solution for a person having average IQ level. 75% of the respondents agreed with the statement. However, 25% are not sure about the understandability.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>75%</td> </tr> <tr> <td>No</td> <td>0%</td> </tr> <tr> <td>Maybe</td> <td>25%</td> </tr> </tbody> </table>	Response	Percentage	Yes	75%	No	0%	Maybe	25%
Response	Percentage											
Yes	75%											
No	0%											
Maybe	25%											
Correctness	Did the labels of phases correctly written?	<p>1- Labeled Correctly (91.7%) 2- Some labels could be improved (8.3%) 3- Some labels are not correct (0%)</p>	<p>Basic aim of this query was to assess the correctness of labels of proposed conceptual model. 91.7% of the respondents agreed with the statement. However, 8.3% are not sure about the correctness</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>91.7%</td> </tr> <tr> <td>No</td> <td>0%</td> </tr> <tr> <td>Maybe</td> <td>8.3%</td> </tr> </tbody> </table>	Response	Percentage	Yes	91.7%	No	0%	Maybe	8.3%
Response	Percentage											
Yes	91.7%											
No	0%											
Maybe	8.3%											
Completeness	Does the proposed conceptual model contain enough details for understandability?	<p>1- enough details are provided (83.3%) 2- need more details (16.7%) 3- Not Sure (0%)</p>	<p>Basic aim of this query was to assess the completeness of details provided for understandability of proposed conceptual model. 83.3% of the respondents agreed with the statement. However, 16.7% said that more details should be added to the model for better understandability.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Enough details are provided</td> <td>83.3%</td> </tr> <tr> <td>Need more details</td> <td>16.7%</td> </tr> <tr> <td>Not sure</td> <td>0%</td> </tr> </tbody> </table>	Response	Percentage	Enough details are provided	83.3%	Need more details	16.7%	Not sure	0%
Response	Percentage											
Enough details are provided	83.3%											
Need more details	16.7%											
Not sure	0%											
Does the information we presented in different phases/components sufficient?	<p>1- sufficient Components (75%) 2- Not Sufficient (0%) 3- Not Sure (25%)</p>	<p>The aim of this question was to assess the completeness of labels or components of proposed conceptual model. 75% of the respondents agreed with the statement. However, 25% are not sure about the completeness of content presented.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>75%</td> </tr> <tr> <td>No</td> <td>0%</td> </tr> <tr> <td>Maybe</td> <td>25%</td> </tr> </tbody> </table>	Response	Percentage	Yes	75%	No	0%	Maybe	25%	
Response	Percentage											
Yes	75%											
No	0%											
Maybe	25%											
Practicality	Does the proposed conceptual model is acceptable by Project managers/Software Requirements Engineers?	<p>1- Practical (75%) 2- Not Practical (0%) 3- Not Sure (25%)</p>	<p>This question is the most critical one as the aim of this was to assess the practicality. 75% of the respondents agreed that this conceptual model possess the practicality. However, 25% of respondents said that this model has potential of practicality after the improvements.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>75%</td> </tr> <tr> <td>No</td> <td>0%</td> </tr> <tr> <td>Maybe</td> <td>25%</td> </tr> </tbody> </table>	Response	Percentage	Yes	75%	No	0%	Maybe	25%
Response	Percentage											
Yes	75%											
No	0%											
Maybe	25%											

Rate each of the criteria with respect to the defined aim - (Out of 5)

1: Strongly Disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly Agree

AIM: (To be filled by the project manager/requirements engineer)				
Role	Does the role have enough qualification?	Does the role is relevant?	Does the role have strong Impact?	Comment/s
	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	<input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5 <input type="radio"/> 1 <input type="radio"/> 2 <input type="radio"/> 3 <input type="radio"/> 4 <input type="radio"/> 5	

FIGURE 19. Sample template of role identification questionnaire.

possessing lack of practical or industrial knowledge. This might bring hollow gap between the perspective of academia and software industry. To mitigate this threat, we evaluated the critical challenges through practitioners from industry. By doing this, we presented both the academic and industrial perspectives.

There might be another possible internal threat, that the acknowledged primary studies have not mentioned the possible reasons behind the mentioned challenges. Basically, the literature lacks in the identification of origin of these challenges in requirements elicitation process. We tried to mitigate its effect by evaluating the challenges from practitioners having real-world experience in industry.

Another validity threat to the current research is that the selected studies have not targeted both traditional and in-house development in one context. The requirements' elicitation challenges are gathered from all the software development approaches. This threat is mitigated by validating the critical challenges from the practitioners of software industry.

The other potential threat is related to the extraction and evaluation of high number of potential studies. However, to effectively mitigate this threat, we followed the guidelines suggested by Kitchenham *et al.* [26].

Moreover, we analyzed the impact significance of requirements elicitation challenges in context of COVID-19 pandemic scenario. The other possible threat might be that different people have different perspective towards development in the pandemic era. To mitigate its effect, we targeted the global audience essential in acquiring the multiple perspectives.

X. CONCLUSION

Software requirements' elicitation is a knowledge-intensive process of knowing or acquiring the stakeholder's needs and goals. The success of requirements elicitation process heavily

grounded on the collaboration, coordination, and most importantly communication among the analyst and stakeholders. However, based on the literature review, we realized that little attention had been paid to the process of transfer of tacit knowledge in COVID-19 context. Inspired by this, we have performed a systematic literature review to extensively gather the requirements elicitation techniques and the challenges that negatively impacts on the requirements elicitation process. After collecting the data from the selected primary studies, we solicited the industry practitioners to identify the requirements elicitation techniques employed to elicit the tacit knowledge explicitly. After that, we categorized and prioritized the challenges by eliminating the possible duplicates and performed frequency analysis.

To empirically evaluate top 15 identified challenges from the literature, we have performed a questionnaire-based survey. In total, 145 global respondents have participated in the performed empirical study. Notice that the majority of the respondents are working in large and medium sized multi-national organizations as a project manager, requirements analysts and software developers. Moreover, we have validated the impact of the categorized top 15 challenges in pandemic scenario context. Finally, we have identified five additional challenges through the performed empirical study. The major classes of the identified challenges are *team size*, *response delay*, *work pressure*, *multiple vendors' involvement*, and *communication infrastructure*.

Considering the identification of stakeholders and transfer of tacit knowledge during communication as most challenging issues, we proposed a conceptual model. The proposed conceptual model identifies the relevant stakeholder and then unfolds the tacit knowledge present in the form of ambiguous statement(s) during elicitation of requirements. To validate the proposed model, we have performed expert validation through a survey. Moreover, a set of mitigation guidelines for the practitioners have been provided, which are useful

AIM: (To be filled by the project manager/requirements engineer)			
Role:	Position Status:		
#	Question	Comment/s	Ranking (Out of 5)
1-	Qualification of role		
2-	Responsibilities of this role		
3-	How role is relevant to the aim?		
4-	Who is the backup role if this employee is not available or absent?		
5-	Decisions that this role is responsible for		
6-	Actions that this role is accountable for		
7-	Typical errors that this role could make		
8-	This role reports to whom		
9-	Benefits if this role is involved		
10-	Consequences if not involving this role		

FIGURE 20. Sample guideline questions.

in mitigating the highlighted effects on requirements elicitation process during the pandemic time. Finally, based on the attained significant results, we believed that proposed conceptual model supports the practitioners in effectively eliciting and gathering the tacit-knowledge based requirements in the COVID-19 context.

APPENDIX A DEMOGRAPHICS OF THE SELECTED PRIMARY STUDIES

See Table 12.

APPENDIX B QUALITY ASSESSMENT SCORE ATTAINED BY PRIMARY STUDIES

See Table 13.

APPENDIX C THE REQUIREMENTS ELICITATION CHALLENGES

See Table 14.

APPENDIX D MODEL VALIDATION RESPONSES

See Table 15.

APPENDIX E PHASE 2 of Proposed Conceptual Model

See Figures 19 and 20.

APPENDIX F CATEGORIZATION OF CHALLENGES

See Figure 8.

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