What Matters in Hiring Professionals for Global Software Development? A SLR and NLP Criteria Clustering

Erivelton Antonio dos Santos, Dalton Garcia Borges de Souza, and Carlos Eduardo Sanches da Silva

***Abstract*—Globalization stimulated a new era of Global Software Development (GSD), followed by the gig economy (GE) phenomenon, which jointly caused considerable transformations in software development markets, mainly after the recent supply chain disruptions. The cultural and geographic barriers have compelled numerous organizations to devise comprehensive digital technologies to overcome this situation. Likewise, the rising unemployment rates led the workforce into short-term contracts or to the on-demand market known as the gig economy. Together with the enhancement in global software development, the organizations found a direction to restore their activities. However, when organizations are immersed in fast-paced environments, selecting skilled professionals is difficult and risky, especially with a lack of qualified professionals. This article identifies the criteria for hiring professionals in the GSD or GE context and proposes a novel approach to clustering them. To do so, we collected the criteria from a broad subject through a systematic literature review, then applied natural language processing with the SBERT algorithm to get the sentence embeddings. Further, we cluster the criteria by applying the *k*-means algorithm. After that, we innovatively and responsively grouped the clusters formed by repeating the SBERT and *k*-means algorithms and created its mind map. Our findings disclosed 319 criteria and 6 cluster groups comprising a mind map hierarchical structure. Consequently, these outcomes have pedagogical implications to assist specialists from education institutions in designing new course domains. Such as, it can be helpful to practitioners to assist in hiring professional processes in the GSD or GE context.**

***Index Terms*—Cluster, criteria selection, hierarchical structure, mind map, NLP, SLR, sentence embeddings.**

I. Introduction

DISRUPTIONS in supply chains have enormous financial impacts and in some cases, cause a permanent loss of market share [1]. Many countries imposed stringent *lockdown* measures to stem the pandemic and relieve exposed populations in [2], [3], [4], [5], and [6]. The contraction of global economic activity resulted in significant demand uncertainties and enormous disruptions in international and national supply chains [6], [7], [8]. However, supply chains are also exposed to other uncertainties, such as large-scale natural disasters, manufacturing fires, terrorist attacks, widespread electrical shutdowns, and financial and political tension [1], [9], and wars [10].

Adopting the latest information and communication technologies and the proliferation of mobile technologies provoked a revolution in the negotiability of outsourcing services. After that, creating a temporary and on-demand job market was soon attainable, qualifying companies through digital platforms to decrease costs and access qualified and specialized labor. This market is known as gig economy (GE) [11], [12].

The fourth industrial revolution has introduced a new era characterized by integrating Big Data and artificial intelligence, leading to the intellectualization of systems [13]. This revolution has resulted in increased demand for projects and software development. At GE, services offered on digital platforms are categorized as software development and technology, with offerings spanning data science, game development, mobile development, Q&A, server maintenance, web development, and web scraping [14], [15]. Within the context of GE, job vacancies and project positions are frequently found in sectors that employ highly skilled IT consultants and technicians from prestigious educational institutions, particularly in financial, professional, and business services [16].

By 2025, there is a prediction to be 42 billion IoT-connected devices globally, state the World Economic Forum (2021). Organizations in all areas with this technology acknowledge that they continue to evolve into data technology companies and that their business standards are being partway or changed by software [17].

Changes in business models, technology, and the global integration of economies mainly affect the ways of working [18], [19]. The essence of qualified work requires substantial flexibility and opening possibilities for self-employed workers [20]. These jobs are generally performed by short-term and flexible contracts, without employment, founded on a digital platform, working for a specified time and a precise task [16], [21]. Employees point out hiring problems in this kind of work, such as the lack of access, autonomy, transparency, communication and accountability, discipline, classification, work allocation, and, in some cases, high costs [15], [21], [22], [23].

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Erivelton Antonio dos Santos and Carlos Eduardo Sanches da Silva are with the Federal University of Itajuba, Institute of Industrial Engineering and Management, Itajuba, MG 37500-903, Brazil (e-mail: erivelton.santos@gmail.com; cadusanches02@gmail.com).

Dalton Garcia Borges de Souza is with the Fluminense Federal University, Institute of Science and Technology, Rio das Ostras, RJ 28895-532, Brazil (e-mail: daltonborges@id.uff.br).

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Enduring in this trendy and global business environment demands overwhelming agile supplier selection process issues [24]. When done accurately, selecting suppliers decreases the company's operating costs and enhances its operational quality [25]. Further, the structured selection of supply partners can improve the effectiveness, efficiency, quality, safety, and profit of companies [26]. Supplier assessment is a multicriteria decision-making problem whose criteria instantiate additional business perspectives. Thus, selecting the proper criteria is a critical prior step to determining the most suitable suppliers [27].

Global software development (GSD) is a contemporary software development approach that has become a direction to develop several economic, quality, and financial benefits [28], [29]. As a result, GSD has been an emerging tendency in software development globally. This scenario boosts the suppliers and consumers in various geographic areas with various cultures and time zones and spreads the development team across numerous locations and countries [30]. Nevertheless, the software distribution dimensions like geographical, cultural, and temporal distances make these activities additionally complex with several challenges [31], [32].

We look at the worldwide modernized software development environment to establish this study's relevance. The technological transition pushes enterprises to focus exclusively on acquiring suitable skill sets to compete at global standards. In October 2022, a Deloitte survey of 116 CEOs pointed out that a shortage of qualified labor was the most significant external is sue encountering their companies, and 71% believe the widespread talent deficiency will persist [33]. Recently, Brazil experienced these challenges, as it lacked some essential skills for the demands of developing new processes [34], [35]. The scarcity of skilled professionals in the technology sector has led companies to adopt innovative approaches to recruitment. A prominent IT firm, for instance, has established a graduate program in Brazil to address this challenge [36].

We analyzed the literature and related works, verifying that many researchers investigated Global Software Development (GSD). Nonetheless, the authors restricted to a particular GSD theme. For example, some authors have examined criteria relating to requirements change management (RCM) in the GSD [32], [37], [38]. Some researchers are dedicated to analyzing the GSD knowledge transfer [39], [40], [41], in finding out the GSD challenges [42], [43], [44], the communication context [31], [45], problems [28], [46], [47], risks [48], [49], success factors [50], [51], [52], and a model proposal [53], [54], [55]. Other researchers dedicated to analyzing the sharing economy environment [19], [56] and others analyzed only the contract side [57].

Also, we can find many systematic literature reviews (SLR) on GSD, team performance [58], follow the sun [59], team communication [60], communication in gig economy (GE) [61], process improvement [62], software integration [50], [53], software quality [63], and requirements implementation [42]. Goyal and Gupta [64] analyzed the team selection but did not demonstrate how they collected the criteria.

In addition, the criteria definition could have been more efficient in several studies [51], [65], [66], compromising the research results and even for comparisons. For this reason, the criteria prioritization results in the studies investigated usually reached different results. We did not find a paper examining the contract's criteria in an open GSD subject.

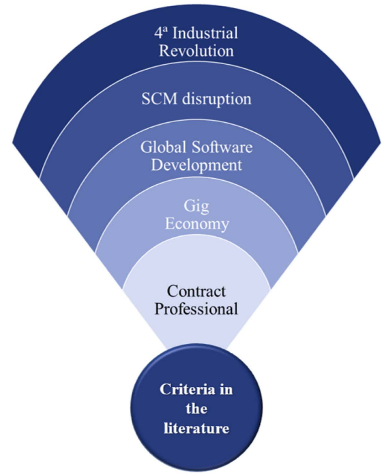

Fig. 1. SLR research delimitation.

Fig. 1 emphasizes the SLR research delimitation, beginning from a broad subject, the fourth industrial revolution, and going inside the disruptions in supply chain management, GE, and contract professionals.

Therefore, this article's research question is linked to an essential topic in the current social and economic situation: how to quickly establish a software development contract in a long-distance and fast-changing environment?

This article identifies the criteria for hiring professionals in the GSD or GE context and proposes a novel approach to clustering them. To do so, we first collected the criteria from a broad subject through an SLR, then applied the SBERT algorithm to get the sentence embeddings. Further, with the sentence embedding obtained, we cluster the criteria by applying the *k*means algorithm. After that, we innovatively and responsively grouped the clusters formed by repeating the SBERT and *k*means algorithms and created its mind map. We summarize the main contributions of this article as follows.

1) We introduce a novel application of natural language processing (NLP) for dimensionality reduction by criteria aggregation instead of multicriteria decision-making (MCDM) or by experience from researchers or practitioners in the GSD context.
2) Through criteria clustering using SBERT and *k*-means algorithms, we create an interactive mind map for better visualization. In addition, this method may support other researchers in grouping criteria responsively.
3) Therefore, this work can be valuable to practitioners to assist in the process of hiring professionals.

The research innovation is in the methodological process, where we are creating a data mining approach for a new SLR using NLP/SBERT for sentence embeddings, and *k*-means clustering an extensive list of criteria instead of using the questionable affinity diagram method. Likewise, creating a hierarchical structure by grouping the clusters formed, using the same approach. To accomplish this goal, the research questions (RQ) of this study are as follows:

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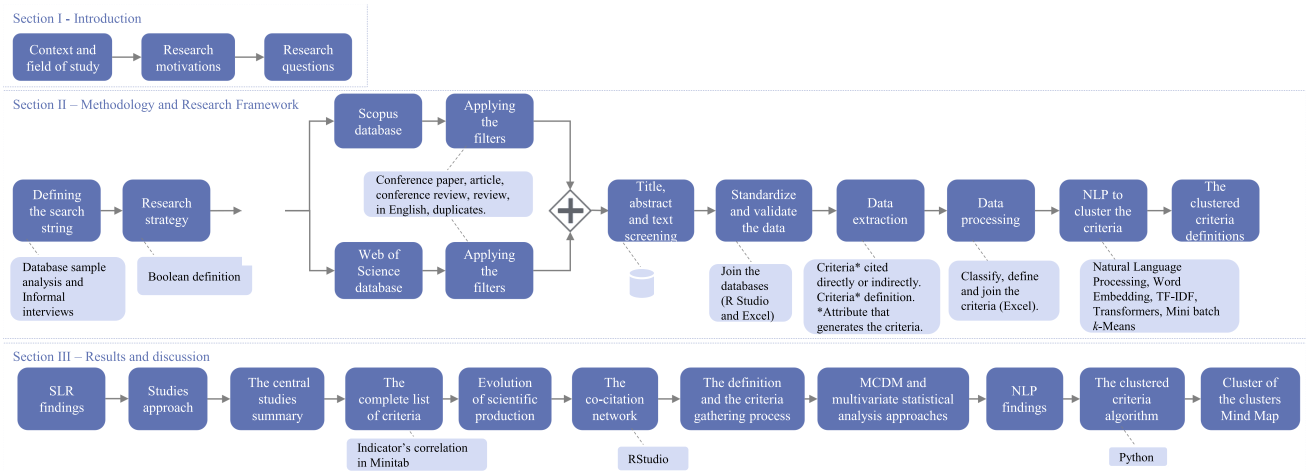

Fig. 2. Research protocol.

1) *RQ1:* Is there any article regarding some selection criteria in the "gig economy" or GSD?
2) *RQ2:* What are the issues, gaps, challenges, barriers, best practices, success factors, risks, and threats for contracting professionals in the "gig economy" or GSD?
3) *RQ3:* What are the most criteria cited in the literature when contracting suppliers, software developers, or hiring professionals in the "gig economy" or GSD?
4) *RQ4:* Can the criteria represent an indicator? What findings can we produce by investigating the SLR results, such as cocitation network and indicators correlations?
5) *RQ5:* Can we cluster the indicators innovatively and responsively?

We organize the article as follows: in Section II, we present the methodology of the SLR and the process of clustering the criteria. In Section III, we present the discussion and the results. Finally, we conclude in Section IV.

II. Methodology and Research Framework

This section introduces the scientific foundations necessary to conduct this research. First, we present the methodology of SLR. Later, we provide an overview of natural language processing (NLP), followed by a section that briefly introduces word embedding, TF-IDF, transformers, BERT, SBERT, and clustering algorithms.

A. SLR—Methodology

The research methodology follows the guidance of Durach et al. [67], Kitchenham and Charters [68], and the PRISMA framework [69] (preferred reporting items for systematic reviews and metaanalyses). In addition, the PRISMA statement plans to aid authors in enhancing the reporting of SLRs through a 27-item checklist [69]. We show these checklists in Appendix A Prisma checklists by the Tables XLIV, and XLV.[1] We built the research protocol shown in Fig. 2 to clarify all the steps performed.

Then, we divide the research protocol into three sections. The first section addresses the motivation behind the literature review and outlines the research questions. This section explains the process of defining the search string, developing the research strategy, selecting the primary database, standardizing and validating the data, conducting the study screening, performing data extraction and processing, and incorporating NLP. Finally, Section III presents the report of findings from the SLR and the results of the NLP clusters.

The next step was constructing a search string before retrieving a potentially relevant literature sample. This process was carried out in two trial steps. First, we did three searches in the Scopus database: search "gig economy" and "selection"; search "supplier selection process" and finally search "global software development" and "digital." We did not include *distributed software engineering* or *distributed software developments* because the recent and modern term is global software development. Then, we validate the search string with a renowned IT company's head and one external specialized science computer teacher in the second step. After accomplishing these two trial steps, we define the first keywords.

In addition to the mentioned keywords, we employed Boolean combinations to explore papers related to supplier selection criteria and conducted a more thorough search in the database. We used keywords such as "selection," "evaluation," "analyze," and "analyze." Through this approach, we collected criteria related to the outsourcing or offshore context, aiming to evaluate the main subject. Additionally, we selected two control articles [37], [64] to validate the Boolean combination and ensure accurate and precise process definition. Finally, Table I shows the searching keywords.

In the title, abstract, and keywords, we searched using the two widely used central databases, namely Scopus, and Web of Science. These databases are considered primary sources for citation data, and their interdisciplinary coverage makes them highly valuable for studying and comparing different scientific fields [70].

However, we can find articles outside those databases; this review's scope remains to only papers obtainable in those two. The search started on July 29th, 2020, and the last update finished

[1]https://bit.ly/Tables-Prisma-Checklists

TABLE I
STRINGS USED TO PERFORM THE SEARCH

Boolean combination (Title, Abstract and Keywords)
"app-work" OR "crowdwork" OR "gig work" OR "on-demand work" OR "independent contractors" OR "gig economy" OR "on-demand economy" OR "digital work" OR "micro-tasking" OR "crowd economy" OR "collaborative economy" OR "amazon mechanical turk" OR "temporary agency work" OR "human cloud" OR "global software development"
AND
"selection*" OR "evaluation*" OR "analyse*" OR "analyze*"

The boolean combination used in the searching process

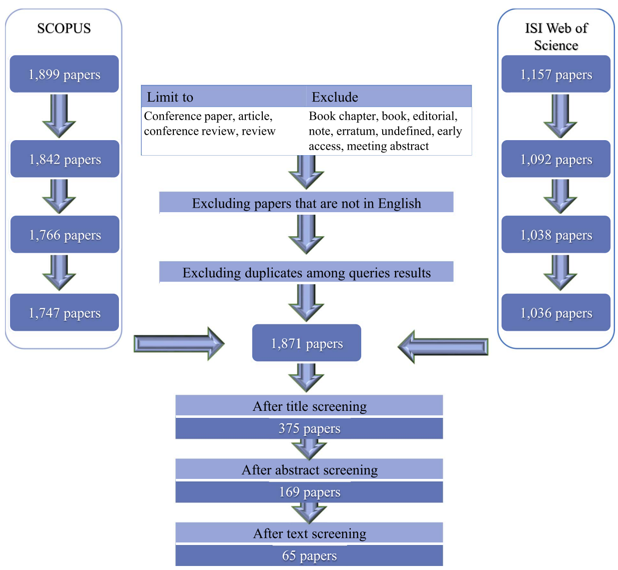

Fig. 3. Searching and selecting process.

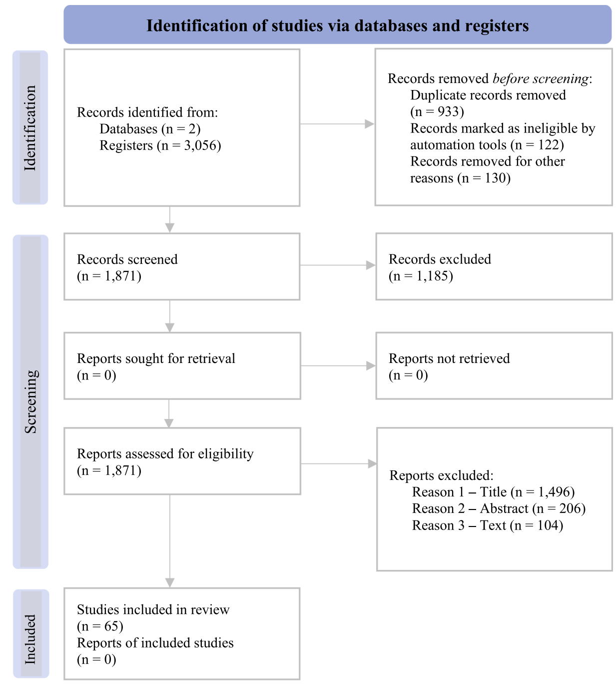

Fig. 4. PRISMA 2020 flow diagram for new SLR, which included searches of databases and registers only.

TABLE II
INCLUSION AND EXCLUSION CRITERIA OF STUDIES

Step	**Study inclusion criteria**	**Study exclusion criteria**
Title	The studies that discuss some of the points related to the research questions.	The studies that do not present approaches or cases related to software development, GE, supplier selection, or hiring process.
Abstract	The studies must address some of the themes related to the research questions. Also, we include secondary studies, like others SLR correlated to the research questions.	Even though some studies do not present the exact context, they were selected for the next step of text evaluation. However, the studies irrelevant to the research questions were left out.
Text	Only studies that presented, directly or indirectly, criteria for supplier selection or software outsourcing relationship.	Furthermore, we excluded studies not related to any criteria for software outsourcing relationships or supplier selection, and we also exclude secondary studies similar to the scope of this study.

The step screening process was the title, abstract, and text of the documents.

on September 9th, 2022. We found 3052 results from 1972 (when the first article is dated) to 2022.

Next, we did a selection process to narrow down the results, using the following filters in Scopus and Web of Science: document type limit to paper (article), conference paper, conference review, and review. Concerning the language, we excluded articles not in English, excluding the duplicated articles among the query results and the duplicated articles between the two databases. Thus, we obtained 1871 articles, assessed for eligibility, as shown in Figs. 3, and 4, complementing the searching and selecting process.

As shown in Fig. 1, the research theme delimitation reveals that we are operating in a marginal region encompassing various themes, which represents an emerging theme. Consequently, we also included proceedings from renowned international conferences. To evaluate the sources and database's reliability and quality, we ranked the corresponding sources according to their classification obtained directly from Scopus, based on their four quartiles.

Then, to determine the characteristics of the subjects or elements under study and to address the research questions, we conducted three screening steps using the inclusion and exclusion criteria outlined in Table II. First, we examined the titles and excluded articles that were not relevant to the scope of this study. Subsequently, we assessed the abstracts of the remaining articles, followed by a full-text review. Each stage also evaluated the inclusion and exclusion criteria in the previous steps. Additionally, all authors independently examined the documents for patterns and reached a final consensus on the database.

We exported the two databases Scopus and Web of Science in Excel files to assemble this process more effectively. We assessed the selected literature in each file considering the study research questions and the inclusion and exclusion criteria, shown in Table II. For the steps Title and Abstract, we evaluated each document using the following Likert Scale: 1 = yes; 0.5 = partial; and 0 = no. We only discard the papers pointed out in these steps with 0 = no. We classified the other documents (1, 0.5) as the next steps. In the third step, Text, we only use the Likert scale: 1 = yes; or 0 = no. The final SLR database contains 65 documents published from 2007 until September 2022, as shown in Tables III–V.

Furthermore, as a sample of the selection process, although the studies of Bartneck et al. [71] and Mitlacher [72] may fit the inclusion criteria, we rejected them because they did not specifically address the GSD contract criteria in a specific way.

TABLE III
ARTICLES INCLUDED IN THE LITERATURE REVIEW—1/3

Author	Year	Title of the document and the number of attributes found	#
Kommeren & Parviainen, [46]	2007	Philips experiences in global distributed software development	17
Chatzipetrou et al., [73]	2011	Software product quality in global software development: Finding groups with aligned goals	14
Dumitriu et al., [74]	2011	Issues and strategy for agile global software development adoption	19
Palacio et al., [75]	2011	Tool to facilitate appropriate interaction in global software development	3
Monasor et al., [76]	2012	Providing training in GSD by using a virtual environment	26
Ilyas & Khan, [53]	2012	Software Integration Model for Global Software Development	19
Lamersdorf et al., [48]	2012	A rule-based model for customized risk identification and evaluation of task assignment alternatives in distributed software development projects	26
Richardson et al., [77]	2012	A process framework for global software engineering teams	25
Baldwin & Damian, [78]	2013	Tool usage within a globally distributed software development course and implications for teaching	3
Humayun & Cui, [40]	2013	An empirical study of the complex relationship between KMR and trust in GSD	1
Nidhra & Yanamadala, [39]	2013	Knowledge transfer challenges and mitigation strategies in global software development—A systematic literature review and industrial validation	18
Avritzer et al., [79]	2014	Survivability models for global software engineering	5
Sangaiah et al., [80]	2015	A fuzzy DEMATEL approach based on intuitionistic fuzzy information for evaluating knowledge transfer effectiveness in GSD projects	10
Sangaiah et al., [54]	2015	A combined fuzzy DEMATEL and fuzzy TOPSIS approach for evaluating GSD project outcome factors	18
Nguyen-Duc et al., [58]	2015	The impact of global dispersion on coordination, team performance and software quality-A systematic literature review	7
Šablis & Šmite, [81]	2016	Agile teams in large-scale distributed context-isolated or connected?	1
Bhatti & Ahsan, [82]	2016	Global software development: an exploratory study of challenges of globalization, HRM practices and process improvement	28
Yaseen et al., [42]	2016	Critical challenges for requirement implementation in context of global software development: A systematic literature review	30
Ilyas & Khan, [50]	2016	An exploratory study of success factors in software integration for global software development vendors	15
Kuhrmann et al., [62]	2016	How does software process improvement address global software engineering?	8
Defranco & Laplante, [60]	2017	Review and analysis of software development team communication research	18
Imtiaz & Ikram, [83]	2017	Dynamics of task allocation in global software development	13
Ilyas & Khan, [43]	2017	Software integration in global software development: Challenges for GSD vendors	14

 # Articles included in SLR, the last column is the number of attributes found.

The SLR database comprises 20 documents from Scopus, four from Web of Science, and 41 from both. We merged these two groups of documents through the RStudio [105].

The Support Information file, SI-file,[2] provides a comprehensive database of the SLR containing the two main worksheets: the Principal Information and Criteria Database. For a quick overview, we have included visual representations of this information in Appendix A, respectively, in Figs. 18 and 19.[3]

TABLE IV
ARTICLES INCLUDED IN THE LITERATURE REVIEW—2/3

Author	Year	Title of the document and the number of attributes found	#
Vizcaíno et al., [41]	2018	A social network to increase collaboration and coordination in distributed teams	6
Gopal et al., [55]	2018	Integration of fuzzy DEMATEL and FMCDM approach for evaluating knowledge transfer effectiveness with reference to GSD project outcome	25
Gulzar et al., [51]	2018	A practical approach for evaluating and prioritizing situational factors in global software project development	40
Kroll et al., [59]	2018	Empirical evidence in follow the Sun software development: A systematic mapping study	3
R. A. Khan et al., [45]	2019	An Evaluation Framework for Communication and Coordination Processes in Offshore Software Development Outsourcing Relationship: Using Fuzzy Methods	7
Vizcaíno et al., [44]	2019	Evaluating GSD-aware: A serious game for discovering global software development challenges	12
Ammad et al., [31]	2019	An Empirical Study to Investigate the Impact of Communication Issues in GSD in Pakistan's IT Industry	44
Sievi-Korte et al., [84]	2019	Software architecture design in global software development: An empirical study	23
Sundararajan et al., [49]	2019	Variation of risk profile across software life cycle in IS outsourcing	10
A. A. Khan et al., [29]	2019	Fuzzy AHP based prioritization and taxonomy of software process improvement success factors in global software development	23
Shanyour & Qusef, [63]	2019	Global Software Development and its Impact on Software Quality	14
Hassan et al., [65]	2019	A Policy Recommendations Framework to Resolve Global Software Development Issues	19
Sridhar & Vadivelu [85]	2020	Satellite phone development through an offshore, outsourcing partnership: Client and vendor experiences	3
Lai et al., [86]	2020	Towards successful agile development process in software outsourcing environment: A systematic literature review	32
Alsanoosy et al., [87]	2020	Identification of cultural influences on requirements engineering activities	13
Akbar, Alsalman, et al., [52]	2020	Multicriteria Decision Making Taxonomy of Cloud-Based Global Software Development Motivators	30
Moayedikia et al., [88]	2020	Optimizing microtask assignment on crowdsourcing platforms using Markov chain Monte Carlo	2
Shameem et al., [28]	2020	Taxonomical classification of barriers for scaling agile methods in global software development environment using fuzzy analytic hierarchy process	21
Akbar, Mahmood, et al., [89]	2020	A multivocal study to improve the implementation of global requirements change management process: A client-vendor prospective	21
A. A. Khan & Akbar, [32]	2020	Systematic literature review and empirical investigation of motivators for requirements change management process in global software development	25
Akbar, M. A. et al., [38]	2020	A fuzzy analytical hierarchy process to prioritize the success factors of requirement change management in global software development	23
Goyal & Gupta, [64]	2020	Intuitionistic fuzzy decision making towards efficient team selection in global software development	18
Hidayati et al., [90]	2020	Hard and soft skills for scrum global software development teams	29
Kamal et al., [37]	2020	Toward successful agile requirements change management process in global software development: A client-vendor analysis	23
Rafi et al., [91]	2020	Multicriteria Based Decision Making of DevOps Data Quality Assessment Challenges Using Fuzzy TOPSIS	3
Kluge et al., [92]	2020	Transformation action cycle: Suggestions for employee centered transformation to digital work in smes	7

 # Articles included in SLR, the last column is the number of attributes found.

[2][Online]. Available: https://bit.ly/SI-FILE-IEEE-TEM
[3]https://bit.ly/Figs-18-and-19

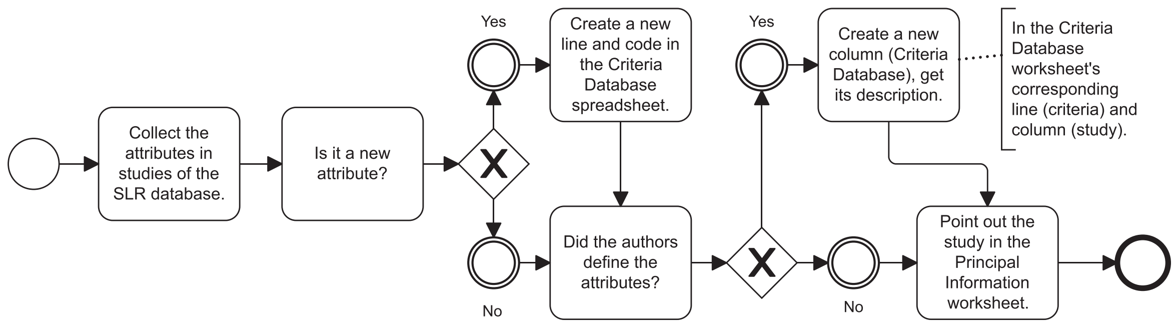

Fig. 5. Data extraction subprocess.

TABLE V
ARTICLES INCLUDED IN THE LITERATURE REVIEW—3/3

Author	**Year**	**Title of the document and the number of attributes found**	**#**
Ali & Lai [93]	2021	Global Software Development: A Review of its Practices	33
Björkdahl & Kronblad [94]	2021	Getting on track for digital work: Digital transformation in an administrative court before and during COVID-19	5
Bastidas, Pardo, & Ardila [95]	2021	A Systematic Literature Mapping: risk-based testing in software development	12
Garro-Abarca, Palos-Sanchez, & Aguayo-Camacho [96]	2021	Virtual Teams in Times of Pandemic: Factors That Influence Performance	7
Zhang et al., [97]	2021	Utilizing Virtual Crowd for Global Software Development	10
Rashid et al., [98]	2021	Green-Agile Maturity Model: An Evaluation Framework for Global Software Development Vendors	23
Rahman et al., [30]	2021	Empirical Investigation of Influencing Factors Regarding Offshore Outsourcing Decision of Application Maintenance	15
Nurrahman et al. [99]	2021	Prioritizing the software development methodologies in online gig economy project using analytic hierarchy process	8
Subbarao & Mahrin [100]	2021	Data Consolidation in Global Software Development Projects: A Grounded Theory	11
Hussain et al., [47]	2021	Prioritizing the Issues extracted for Getting Right People on Right Project in Software Project Management from Vendors' Perspective	14
Khan & Akbar [101]	2022	Software development process evolution and paradigm shift - a case study of Malaysian companies	9
Castro-Hernandez et al. [102]	2022	Effect of Temporal Patterns on Task Cohesion in Global Software Development Teams	3
Rafi et al., [103]	2022	Decision-Making Taxonomy of DevOps Success Factors Using Preference Ranking Organization Method of Enrichment Evaluation	16
Iqbal et al., [66]	2022	Model to Cope with Requirements Engineering Issues for Software Development Outsourcing	42
Ludwig et al., [61]	2022	Communication in the Gig Economy: Buying and Selling in Online Freelance Marketplaces	4
Trinkenreich et al., [104]	2022	An Empirical Investigation on the Challenges Faced by Women in the Software Industry: A Case Study	8

 # Articles included in SLR, the last column is the number of attributes found.

Where the first worksheet holds the principal data information and statistical data of the studies in the SLR and the second holds the secondary details as the criteria definitions. We also use this secondary worksheet to create the criteria indicator groups, aiming to calculate their correlation.

We thoroughly read all the documents in the database and sorted and analyzed them according to the research protocol, see Fig. 2, and the subprocess of data extraction shown in Fig. 5. Thus, authors 1 and 2 extracted the attributes using the spreadsheet SI-file and independent collection; then, author 3 revised and validated the theoretical list of criteria. Consequently, we searched for attributes related to software outsourcing relationships or contracting professionals in the gig economy or GSD in these 65 studies. These attributes included issues, gaps, challenges, barriers, best practices, success factors, risks, and threats.

For example, we read the document [31] searching for new attributes, following the subprocess data extraction, shown in Fig. 5. Before picking a new attribute, we check in the Criteria Database worksheet to see if it is already present and observe its description. If it is a new attribute, for example, Low Quality of Telecommunication Bandwidth (C247), we create a new line with a sequence code, attribute name, and description (when it exists).

Following, suppose the attribute is already present in the SLR database. In that case, we have two options. First, suppose the study has defined the attribute. For example, see geographical dimension (C062), which is only defined by four studies [58], [48], [31], and [66]. In that case, we create a new column and put the attribute name and description in the Criteria Database worksheet's corresponding line (criteria) and column (study).

Second, suppose another study indicates the same attribute but does not define it. In this case, we only point out the study in the Principal Information worksheet. As a result, examining the Principal Information worksheet for this criterion (C062), we observed in the SLR database 16 times, four times defined, and 12 not defined.

As described in the Criteria Database worksheet, the columns are organized in the following order: code, collected attributes, criteria, types of criteria (specific, measurable, achievable, relevant), and two columns dedicated to the criteria definitions. In sequence, each column represents a reference obtained from the SLR that defined at least one attribute (see Fig. 19). However, if a study did not define any attribute, its reference will not be included in the criteria database worksheet column. Likewise, empty cells in these columns or the absence of certain studies in this worksheet indicate that they did not provide a definition for the criterion. Once these steps of Fig. 5 were completed, we compiled all the available definitions in the SLR database and merged them into the all-criteria definitions column.

Indeed, the process of the criterion definitions is critical to NLP and clustering steps. To have a complete database reference, as some criteria were not defined within the SLR database, we added the "External Reference" column to indicate the definition's source. We primarily obtained these external references by conducting searches on Google Scholar.

Algorithm 1: Pseudocode of Criteria Definition Method.

```
FOR (Documents = 1, 2, ..., 65) do
  For Attributes = 1, 2, ... N do
    Collect the Attributes for any Documents
    Place in their respective Code row.
    Place in their respective Documents column.
  end for
end For
FOR Criteria = C_001, C_002, ..., C_nnn do
  For each Documents column and Code row
    Merge all criterion definitions into its column.
    Assemble a standard definition (SDF) (another
    column).
    Remove the references in SDF for the NLP process.
    Check the spelling and grammar with
    https://app.grammarly.com/software.[2]
end For
```

In the second column of the group on the criteria definitions, titled "Final Criteria Definition (for NLP)," in the Criteria Database worksheet of SI-file, we formulated a standardized definition (SDF) for each criterion. An SDF stands for the one that best represents the concept of the criteria. These definitions were based on the context of GSD and the gig economy, which were gathered from the SLR database. Subsequently, we removed the references in SDF to prepare the dataset for the NLP process and utilized software[4] to verify spelling and grammar accuracy. We present these criteria descriptions with their references in Section III-A3. The complete list of criteria, and in the SI-file without reference. Hence, we finish preparing the dataset for the NLP process.

The pseudocode 1 summarizes these steps, where the criterion "code" begins with a sequential number of C_{001}, C_{002},..., C_{nnn}; $n = 0, 1, \ldots, 9$, and C_{nnn} will be the last one criterion.

We worked with the criteria database worksheet parallel to the Principal Information worksheet. The Principal Information worksheet includes all the documents obtained from Scopus and Web of Science, with each line representing a single document. The worksheet contains three groups of information: document details, study approach, and criteria code (see Fig. 18).

In the first group, we recorded all the document details and used a Likert scale to indicate whether the study's cited attribute (collected criteria) was defined or explained. We created a new column "X" for this purpose, with values of 1 for "several" (almost all criterion was defined), 0.5 for "partially defined" (just some criterion was defined) and 0 for "not defined." In the second group, we followed a similar process for the study approach, as shown in Section III-A1—The studies approach. In the third group, we created new columns for each criterion (C_{001}, C_{002},..., C_{nnn}) and linked them to their respective references to gather statistical data, as shown Fig. 5 final step.

We define the group of the criteria as an indicator following the SMART KPI's [106], [107], as shown in Table VI. This Table VI encounters the leading indicator criteria group: specific, measurable, achievable, and relevant. Then, in the following line, we find the questions used to classify each criterion. Finally, the

[4][Online]. Available: https://app.grammarly.com/

TABLE VI
GROUPING THE CRITERIA AS AN INDICATOR

Indicator Group (IG)	Description	Type
Specific - IGS	How is the availability of the indicator?	Direct
		Indirect
Measurable - IGM	What is the approach of the indicator?	Qualitative
		Quantitative
		Quali-quanti
Achievable - IGA	How reasonable and attainable is it?	Objective
		Subjective
Relevant - IGR	Where can we measure?	Inside.
		Outside
		Both

TABLE VII
DEFINITION OF INDICATOR GROUP TYPES

Indicator Group	Type	Definition
Specific	Direct	The criterion is explicitly presented.
	Indirect	The criterion is not explicitly presented, and its data is inferred from the papers.
Measurable	Qualitative	A qualified (as Likert scale) level measurement controls the criterion.
	Quantitative	A quantified level measurement controls the criterion.
	Quali-quanti	A Quali-quanti group type could be both qualified and quantified.
Achievable	Objective	The indicator's values are clear to achieve under given conditions and in the foreseeable period.
	Subjective	The criterion needs one qualified level to be measured.
Relevant	Inside	The criterion is realistic and results-oriented (local) the organization.
	Outside	The criterion is realistic and result-oriented outside (vendors) of the organization.
	Both	The criterion is realistic and result-oriented inside and outside the organization.

criteria were classified as direct and indirect, objective and subjective, qualitative, quantitative and quali-quanti, inside, outside, and both, observing their exact group. Moreover, we used the "dummy encoding" or "one-hot encoding" for each category (indicator group), and we calculated their correlation through a statistics package Minitab [108]. So, we applied the Pearson correlation coefficient, a linear correlation coefficient for measuring the relationship, or association, of two variables [109].

Afterward, with the criteria groups definition, we explained each type of group, as shown in Table VII.

The following characteristics delimited the outcomes of this work: we perform the SLR limited to Scopus and Web of Science Core Collection. Consequently, we can find other articles and studies on the subject in other databases; the keywords used to find articles and studies may not be enough to return all possible viable results. This work focuses on attributes, criteria, and cluster selection steps. Other steps, such as the selection of decision-makers, application in project hiring, and schedules, are not included in the scope of this study. Furthermore, to overcome this research delimitation, we analyzed the cocitation network through the bibliometrix package [110] in R and RStudio software [105] to build the cocitation network figure, aiming to meet an entire list of criteria with snowball searches by the cocitation network [111], [112] Moreover, using the same package, we also analyzed the evolution of scientific production.

In the subsequent section, we present how we grouped the list of criteria. We could use traditional or new approaches starting from the complete definition of the criteria list. The conventional method involves using the *Affinity Diagram* tool, which gathers significant amounts of language data (ideas, opinions, issues) and organizes it into groupings based on the natural relationship between items. This process is predominantly creative rather than relational. It allows the organization of qualitative data collected from customers and other stakeholders to identify themes, issues, and concerns [113], [114]. However, in our study, we opted to employ NLP techniques and *k*-means clustering, which provides a more analytical and quantitative approach to clustering.

B. Natural Language Processing

This section presents NLP and the clustering approach to group the criteria list.

NLP, a field within computational linguistics, involves the computer's ability to select the appropriate sense of a word in a given context. It aims to enable computer systems to comprehend and process natural language for specific tasks [115]. This section explains how sentences are represented as numeric matrices, which serve as embeddings for machine learning [116]. Additionally, the ection introduces the required algorithms used in this context.

NLP employs computational techniques to learn, understand, and generate human language content [117], [118], [119]. It has gained significant prominence due to the widespread adoption of the World Wide Web and digital libraries [118], [120]. NLP finds numerous applications, often in conjunction with information retrieval (IR), structured and unstructured data mining (DM), and machine learning techniques. These applications include sentiment analysis, opinion mining, subjectivity analysis, and detecting deception and lie within text [121], [122].

The most commonly employed machine learning techniques are supervised machine learning methods and systems, such as spam classifiers for e-mails, facial recognition tools for images, and patient diagnosis systems. Hence, the training data form a collection of *(x, y)* pairs, and the goal is to create a prediction $y*$ in response to a query $x*$ [122]. Indeed, NLP is a powerful tool widely used [123].

Statistical NLP has emerged as the preferred approach for modeling complex natural language tasks. However, its development has often faced the challenge of the curse of dimensionality when attempting to learn joint probability functions of language models. Therefore, to tackle this issue, the concept of learning distributed representations of words in a low-dimensional space was introduced [124]. Thus, word embedding, TF-IDF (term frequency-inverse document frequency), and transformers concepts have emerged [124], [125], [126].

The transformer model is a powerful alternative to traditional sequence-aligned models like RNNs, relying on self-attention for input and output computations [127], [128]. It consists of an encoder and a decoder with feed-forward and attention layers. Unlike RNNs, which process words individually, transformers analyze entire sentences [129], [130]. The attention mechanism, including scale dot-product attention and multihead attention, allows for comprehensive context understanding [128]. This breakthrough has led to remarkable progress in NLP tasks, exemplified by BERT, heralding a new era of performance.

1) BERT and SBERT: The latest refinements in NLP have acquired substantial awareness due to their efficiency in language modeling [127]. The large-scale, publicly available pretrained language models released are ELMo, OpenAI, and Google to compare generative models in NLP [131]. Deep learning and pretraining models have recently demonstrated excellent results in several language tasks. Particularly fine-tuning the pretrained models such as Embeddings from Language Models (ELMo), OpenAI GPT (generative pretraining), GPT-2, and bidirectional encoder representations from transformers (BERT) has become the best practice for state-of-the-art results [132].

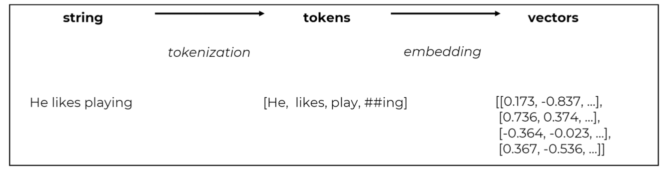

Fig. 6. Sequence and sentence size representation.

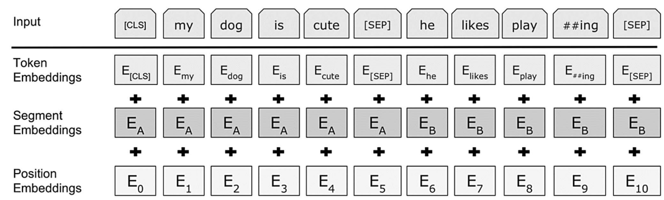

Fig. 7. BERT input representation.

BERT revolutionized the field of NLP by achieving state-of-the-art performance in various tasks. It combines the principles of transformer and bidirectional training, using language masking to create a contextual and distributive representation of each input token. BERT employs a bidirectional masked language model to predict masked words, enhancing contextual information. This approach allows BERT to handle sequences of one or two sentences, enabling its application in multiple downstream tasks. The flexibility of BERT's input representation contributes to its success in NLP [120], [127], [133].

The initial token of each sequence is a specific classification token denoted by [CLS]. The ultimate hidden state associated with this token represents the comprehensive sequence representation for classification purposes. To handle sentence pairs, they are combined into a single sequence and distinguished from each other through two methods. First, they are separated by a distinct token [SEP]. Second, each token is assigned a learned embedding, indicating whether it belongs to Sentence A or B. Equation (1) shows these representations [120]

$$[\text{CLS}] + \text{Sentence}_A + [\text{SEP}] + \text{Sentence}_B + [\text{SEP}] \quad (1)$$

where [CLS] is a special classification token and [SEP] is a special separation token.

Moreover, Fig. 6 illustrates one sentence's tokenization, embedding, and vectorization processing.

One of the advantages of utilizing this architecture is that we can have diverse sentence sizes. Fig. 7 displays BERT input representation construction visualization. The input embeddings are the sum of the token, segmentation, and position embeddings, where E stands for the input embedding, the final hidden vector of the unique [CLS] token as $C \in \mathbb{R}^H$, and the final hidden vector for the i th input token as $T_i \in \mathbb{R}^H$. Its input representation is constructed for a given token by summing the corresponding token, segment, and position embeddings [120].

The BERT architecture follows conventional and autoregressive (AR) language modeling. The BERT maximize the likelihood between the tokens x in a text sequence $x = [x_1,..., x_T]$ in the pretraining process. Allow $\hat{x}$ to represent the same text

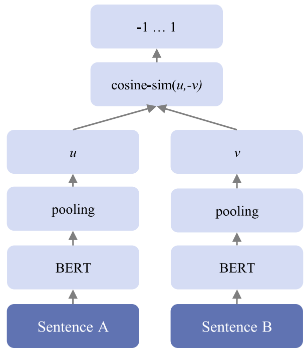

Fig. 8. SBERT architecture at inference—computing STS scores.

sentence with masked tokens and $\bar{x}$ to be an array of masked tokens. The training objective of BERT is to rebuild $\bar{x}$ from $\hat{x}$.

BERT takes that all masked tokens $\bar{x}$ are mutually independent, which is the primary rationale behind the approximation of the joint conditional probability $p(\bar{x}, \hat{x})$. For more details, see the study [134].

One limitation of the BERT network architecture is the lack of independent *sentence embeddings*, making it challenging to obtain them directly from BERT. *Sentence embedding* represents sentences in an n-dimensional vector space to capture their semantic equivalence. It captures the meaning of a sentence by considering different word expressions within their context [135]. To address this, researchers process individual sentences through BERT and obtain a fixed-sized vector by averaging the outputs (similar to average word embeddings) or utilizing the output of the distinct CLS token [134].

SBERT is a customized version of the pretrained BERT model that utilizes Siamese and Triplet Network Architectures for generating sentence embeddings that are semantically significant. The two subneural networks assemble the Siamese network. Each subneural network carries data, maps it to a high-dimensional characteristic space, and outputs the resultant representation. Investigators can compare the similarity of two input sentences by calculating the distance between the two representations, such as cosine distance [136].

SBERT can be compared by using cosine similarity. We selected the SBERT model, which is qualified for efficient semantic similarity search and clustering [137]. The quality evaluation of SBERT on various standard benchmarks notably improves over state-of-the-art sentence embedding methods [134]. SBERT performs efficient sentence embedding by comprehending that operating the average for BERT's output vectors [138].

Moreover, SBERT comprises two BERT networks, where each one receives a sentence as input. The similarity score between two input sentences is determined by computing the cosine distance between their respective sentence embeddings u and v. SBERT executes a pooling operation on the BERT output to generate a fixed-sized sentence embedding. Fig. 8 illustrates the SBERT architecture for calculating similarity scores. Furthermore, we have enhanced the inputs and outputs of BERT in SBERT [136], [137].

We used the sentence-BERT (SBERT) pretrained BERT network in this work. Moreover, we choose the model name "all-mpnet-base-v2" due to its high performance in semantic search.[5] We utilized a Python library based on the deep learning framework PyTorch and the transformers repository of Hugging Face, Inc.

Then, aiming to cluster the entire list of criteria, once we calculate the above process of sentence embeddings in a Python framework, we compare each criterion against each other using the k-means clustering.

C. K-*Means Clustering*

Cluster analysis, or data segmentation, or simply clustering, is a process of grouping (partitioning) large datasets into groups (partitions) according to their similarities [139], [140]. Thus, cluster analysis aims to decrease a dataset's dimensionality by identifying homogenous data groups [118], [141]. Clustering is currently applied in various domains such as machine learning, pattern recognition, image analysis, information retrieval, bioinformatics, data compression, computer graphics, archaeology, psychology, and marketing by practitioners [121], [140].

Cluster analysis involves identifying the characteristics of variables for data segmentation and selecting an appropriate clustering method. Commonly used methods include k-means and mini-batch k-means, known for their stability and reliable outcomes. The number of clusters is determined either by rules or expert knowledge. Clustering results are interpreted based on the underlying theory and research domain. Nonhierarchical or partitional clustering methods offer linear complexity and efficient handling of large datasets by considering data point centers as cluster centers. They require fewer iterations and are suitable for diverse applications [139], [141], [142], [143].

Although many other clusterings algorithms have been developed, k-means stays one of the most widely employed methods due to its clarity, ease of performance, speed of selecting the cluster center, and efficiency [139], [144].

The k-means algorithm seeks to divide m objects in n dimensions into k (where $k \leq n$) partitions (or clusters), minimizing the sum of squares within the cluster. The resulting intracluster similarity is high (minimal within-clusters sum of squares). In contrast, the intercluster similarity is low (maximum between-clusters sum of squares). Unlike hierarchical techniques, k-means produces a flat cluster structure. Furthermore, the pair of objects' distance defines their similarity, where the practitioners broadly utilize Euclidean distance for measuring. Finally, the partition divides the data into k groups, so each group contains at least one object [139], [144].

Given a group of objects, the primary purpose of the k-means clustering is to optimize the within-clusters sum of squares (WSS) as the following objective function:

$$WSS = \sum_{j=1}^{k} \sum_{i \in C_j}^{n} ||x_i^j - c_j||^2 \quad (2)$$

where k is the number of clusters, n is the number of objects, x_i is the ith element in the cluster, and c_j is the centroid of the jth cluster [139]. This algorithm demands the number of clusters to be specified. However, it scales satisfactorily to a large number of samples and has been used across a comprehensive range of application areas in many different subjects [140].

[5] [Online]. Available: https://www.sbert.net/docs/pretrained_models.html

The data clustering steps using the k-means method [139], [144], [145], as follows:

1) First, specify the number of clusters k.
2) Next, initialize k values as cluster centers (centroids) haphazardly.
3) Group each data into the nearest cluster by calculating the closeness of two data using Euclidean distance.
4) Recompute each centroid by calculating the mean of all centroid data with recent cluster members.
5) Recluster each data (go back to step 3) utilizing all new centroids until all centroids converge and stop changing.
6) Finally, if the centroids have not changed, the clustering process is finished.

One of the central problems of the k-means method is selecting the optimal number of clusters k. There is no assurance that k-means discovers the global minimum, but it does discover a local minimum for a provided initial selection of centroids. With a proper selection of the initial value and the number of clusters, practitioners have demonstrated that the accuracy of the k-means method can be higher [144], [146]. The pseudocode 2 shows the k-means method [147].

Algorithm 2: k-means Pseudocode.

```
Input : The criteria (C_001, C_002,..., C_nnn) obtained in the SLR.
Output : The clustered criteria (g_0, g_1,..., g_n).
Decide and insert the number of clusters k.
Randomly select distinct data points as initial cluster centroids;
While Clustering condition is not satisfied, or centroids do not change do
   Compute the objective function, defined in (2);
   Assign each data point to the closest cluster;
   Update the cluster centroids;
end While
```

We apply the k-means clustering approach in a Python framework. Moreover, we used the elbow method to support finding the best cluster number.

The elbow method is a visual approach to determine the optimal value of k in k-means clustering. It calculates the within-cluster sum of squares (WCSS), the sum of squared distances between data points, and their assigned cluster centroid. The resulting WCSS values for different values of k are plotted on the y-axis against k values on the x-axis. We select the k value at the elbow joint, where the graph shows a sharp change in slope. Increasing k beyond this point does not significantly decrease WCSS [148].

We created a cluster group of the clusters and its mind map. As we had many clusters aiming to develop an innovative and responsive model to present the data, we repeated this process with the clusters formed. Although there is an algorithm to create descriptive labels of the clusters automatically [137], after achieving the proper criteria clusters, we build the word cloud for each cluster to help create cluster names.

III. Results and Discussion

This section presents the results and discussion of the SLR in the following Section III-A and the criteria clustering results in Section III-B.

A. SLR—Report the Findings

This section shows the report of findings composed of the following topics: the studies approach, the central studies summary, the theoretical list of criteria for contract professionals, the evolution of scientific production, the cocitation network, the definition, and the criteria gathering process, and multicriteria decision-making approaches.

1) The Studies Approach: The approach of the studies and the authors are shown in Table VIII. We based and adapted the approach by de Araújo Lima et al. [149] for this construction. We split the approach of the studies according to *research methodology*, *process setup*, and *analysis scenario*. We also divided this primary approach into subcategories. The *research methodology* comprises a single case study, multiple/long case study, literature review, conceptual model proposal, model and test proposal, and survey/interview.

We classify the research methodology as follows:

1) Survey/interview, when the researchers used a questionnaire or made one or more interviews.
2) Literature review, when the researchers made a simple literature mapping or an SLR to find the criteria.
3) Conceptual model proposal, when the researchers proposed a tool.
4) Single case study when they focused on only one stakeholder.
5) Multicase/long case study when they focused on two or more stakeholders;
6) Model proposal and test when the researchers tested the model with the stakeholder.

In some cases where there is more than one methodology in the same study, we pointed out both methodologies. The picked primary studies consist of 62% survey/interview, 51% literature review, 29% conceptual model proposal, 18% single case study, 14% multicase/long case study, and 9% model proposal and test.

The second approach is the *process setup*, which includes context analysis, identification, evaluation, treatment, and monitor and report. We classify the process setup as follows:

1) Context analysis when the researchers investigated the criteria in a general perspective.
2) Identification when the researchers are looking for new criteria.
3) Evaluation when the criteria pass throw for some data analysis.
4) Treatment when the criteria pass by a more robust process methodology.
5) Monitor and report when the model proposed is returned in a survey or similar for validation.

The *process setup* consists of 54% of evaluation, 37% identification, 34% treatment, 29% monitor and report, and 29% context analysis.

The third was the *analysis scenario:* problems, issues, gaps (fact), challenges, barriers, risks and threats, and best practices and success factors. To separate this category, we followed

TABLE VIII
APPROACH OF THE STUDIES AND AUTHORS

The approach of the studies	Type	Studies and authors
Research methodology	Survey/interview - 62%	[28]–[32], [37]–[41], [43], [45]–[49], [51], [54], [55], [65], [75], [78], [80]–[84], [86], [89]–[92], [96], [98]–[104]
	Literature review - 51%	[28]–[32], [38], [39], [42], [43], [45], [47], [49]–[53], [58]–[60], [62]–[65], [77], [82], [83], [86], [87], [89], [91], [93], [98], [103]
	Conceptual model proposal - 29%	[38], [41], [44], [48], [51], [54], [55], [61], [73]–[77], [81], [84], [87], [88], [95], [97]
	Single case-study - 18%	[41], [46], [55], [64], [73], [78], [79], [81], [83], [85], [94], [104]
	Multi-case/ Long study - 14%	[39], [40], [45], [48], [51], [53], [54], [84], [98]
	Model proposal and testing - 9%	[31], [52], [64], [66], [79], [82]
Process setup	Evaluation - 54%	[28]–[32], [37]–[41], [43], [46], [48], [50], [51], [53]–[55], [58], [62], [64], [65], [73], [76], [79]–[84], [89], [91], [98], [100], [103]
	Identification - 37%	[29], [32], [39], [40], [42], [43], [47], [49], [53], [58], [59], [62], [64], [65], [82]–[84], [86], [89], [91], [93], [95], [99], [101]
	Treatment - 34%	[28], [29], [31], [38]–[40], [45], [47], [49], [53], [54], [66], [75], [82]–[84], [89]–[91], [96], [104]
	Monitor and report - 29%	[28], [29], [31], [32], [39], [44], [46]–[48], [52], [64], [75], [82], [84]–[86], [89], [91]
	Context analysis - 29%	[29], [38], [41], [44], [46], [55], [60], [61], [63], [64], [74], [78], [81], [87], [88], [92], [94], [97], [102]
Analysis scenario	Problems/issues/gaps (Fact) - 46%	[31], [37], [40], [42], [46], [47], [55], [59]–[61], [63], [65], [74], [75], [77]–[79], [82], [84], [85], [87]–[89], [92], [93], [96], [97], [99], [101], [102]
	Best Practice/Success factor - 34%	[29], [32], [37], [38], [51], [54], [55], [73], [76], [77], [82]–[84], [86], [89], [90]
	Challenges/Barriers - 31%	[28], [39], [41]–[45], [52], [53], [58], [62]–[64], [74], [77], [81], [82], [84], [91], [104]
	Risks and threats - 11%	[48], [49], [62], [77], [94], [95], [98]

The first column is the approach of the studies, the second is the type and their percentage, and the third column is the studies and authors.

the Author's classification; in cases of doubts, we classify the *analysis scenario* as follows:

1) Problems/issues/gaps when we recognized that it was a fact occurred.
2) Challenges/barriers when the scenario was not a fact, or the researchers proposed a mitigation process.
3) Best practices/success factors when the researchers collected the criteria from successful cases.
4) Risks and threats when the researchers look for the criteria in the literature or stakeholders.

Like the others, where there is more than one result in the same study, we pointed out both. Similarly, the *analysis scenario* consists of 46% of problems/issues/gaps, 34% challenges/barriers, 31% best practices/success factors, and 11% risks and threats. The following section presents some of these in the central studies summary.

2) The Central Studies Summary: This section shows the most cited documents and those that contributed with more attributes. We begin with central studies. We consider the attributes as any situational factor in scenario analysis, like problems, issues, gaps, challenges, barriers, risks, threats, best practices, success factors, or another characteristic involving the GSD.

The most cited document in the SLR was made by Nidhra et al. [39], which provided a body of knowledge for enabling successful Knowledge transfer in GSD settings. The authors made an SLR to collect the data and interviewed experienced industry professionals from eight multinational companies worldwide. This well-structured work maps the challenges with mitigation strategies to guide practitioners in electing strategies when faced with different KT challenges.

The second, Nguyen-Duc et al. [58], summarizes empirical proof of global dispersion dimensions' impact on coordination, team performance, and project outcomes. This study consistently conceptualized the global dispersion dimensions but quantified them differently. In addition, the study reveals that geographical and temporal dispersion is linked with a particular set of coordination challenges, such as the influence on task resolution duration, software quality, and objective team performance.

Following the experience of ten years of GSD at Philips made by Kommeren and Parviainen [46], was the third document cited. This work shows an inspiring figure made in 2007 that predicts rising external software development, or GSD environment, which is very close to what happened, as shown in the SLR database. They collected the data through a standardized questionnaire of over 200 projects in various locations, including offshoring and outsourcing environment. The authors inferred that these projects allocated over 50% of development effort to project management and team coordination. We may assume that this older and highly cited work attracted other publications as Nguyen-Duc et al. [58], the second paper most cited.

In sequence, Richardson et al. [77] did the fourth most cited paper, which investigated the GSD teams. Based on three previous works, from the factors and risks collected, the authors proposed one integrated model of global teaming practices to meet the growing needs of development teams operating in a global environment. They made a Global Teaming framework comprising two goals and five specific practices: global task management, knowledge and skill management, global project management, operating system, and collaboration between locations. Finally, they validated this framework with a presentation for 10 senior and project managers.

The other central part is the attributes collected from the SLR database. With 44 attributes collected, we highlight the work made by Ammad et al. [31]. They conducted an SLR to identify the factors influencing communication in GSD, categorized them into eight distinct categories, and proposed a conceptual framework. Subsequently, they designed a questionnaire that received 202 responses. The partial least squares-structural equation model was employed through multivariate analysis to validate the proposed framework. The authors precisely defined all 44 identified issues, which were discussed as vulnerable points in various documents mentioned in the previous section.

Subsequently, Iqbal et al. [66] contributed 42 attributes to the study. The authors presented a requirements engineering practices (REP) model to address common issues in Software Development Outsourcing (SDO). To accomplish this, they conducted a root cause analysis and organized five workshops, totaling 60 Man-hours. During these workshops, they identified 89 root causes related to the 43 common issues in the SDO requirements engineering (RE) process. Furthermore, utilizing the brainstorming technique, they identified and proposed 124 relevant REP to mitigate the 89 root causes and address the 43 common issues in the SDO REP.

The third significant contribution came from Gulzar et al. [51], who contributed 40 attributes to the study. Before conducting interviews with software development teams, the authors administered an online questionnaire to gather information on critical situational factors in global software project management. Subsequently, they categorized and prioritized these situational factors using the fuzzy analytic hierarchy process. The authors concluded that the Trust group emerged as the primary influential factor in project development.

TABLE IX
INDICATOR GROUP TYPES CORRELATION

Indicator type	Correlations	IGS_Direct	IGS_Objective	IGM_Qualitative	IGM_Quantitatitave	IGM_Quali-quanti	IGR_Both	IGR_Inside
IGA_Objective (n:146)	Pearson correl.	0.788						
	P-Value	0						
IGM_Qualitative (n:133)	Pearson correl.	-0.594	-0.649					
	P-Value	0	0					
IGM_Quantitatitave (n:25)	Pearson correl.	0.219	0.294	-0.247				
	P-Value	0	0	0				
IGM_Quali-quanti (n:161)	Pearson correl.	0.468	0.482	-0.854	-0.294			
	P-Value	0	0	0	0			
IGR_Both (n:241)	Pearson correl.	0.023	0.025	-0.066	-0.024	0.078		
	P-Value	0.687	0.658	0.238	0.668	0.163		
IGR_Inside (n:55)	Pearson correl.	0.050	0.030	0.018	-0.010	-0.013	-0.802	
	P-Value	0.373	0.588	0.749	0.865	0.823	0	
IGR_Outside (n:23)	Pearson correl.	-0.111	-0.086	0.084	0.054	-0.112	-0.049	-0.127
	P-Value	0.048	0.126	0.135	0.336	0.046	0	0.023

Pearson correlation, P-Value, and the numbers of criterion collected "n".

Finally, we present the entire list of criteria for what matters in hiring professionals for GSD.

3) The Complete List of Criteria: After full-text reading of all documents, we collected the attributes, linked them with each paper, and grouped and classified them. Then, we convert them into criteria for supplier selection in the GSD environment.

Tables XXXVI, XXXVII, XXXVIII, XXXIX, XL, XLI, XLII, and XLII in the Appendix A—Criteria list for contracting professionals in GSD shows the complete list of criteria.[6] We organized these tables with the first column of presents the criteria code, the second column showing the attribute collected on the references, the criteria name, and the definition in sequence, and the last column displaying the number of citations and the percentage.

Consequently, to have statistical analyses of the indicators groups, see Tables VI, VII, and the criteria, we use the "dummy encoding" or "one-hot encoding" to calculate their correlation, as shown in Table IX.

Nevertheless, due to their opposing nature, we did not calculate the correlation between the Indirect × Direct and Subjective × Objective groups, resulting in an entirely negative Pearson correlation coefficient of (−1.0). The Objective × Direct group exhibits a strong positive correlation coefficient (0.788), primarily due to the similarities observed in the specific and achievable subgroups. Conversely, the Quali-quanti × Qualitative and Inside × Both groups demonstrate strong negative Pearson correlation coefficients (−0.854 and −0.802, respectively), as they tend to be opposites. Furthermore, the Qualitative × Direct (−0.594) and Qualitative × Objective (−0.649) groups display moderate negative correlation coefficients. This is because if a criterion is "direct" and "objective," it tends to fall into the "quali-quanti" or "quantitative" category, as indicated by the moderate positive correlation coefficients (0.468 and 0.482) observed in the Quali-quanti × Direct and Quali-quanti × Objective groups, both with a p-value of zero.

Afterward, we emphasize the 14 highly cited criteria in SLR. The highly cited criteria in decrescent order point out were communication (51%), trust-building (43%), cultural differences among teams (42%), coordination challenges level (40%), temporal distances (34%), knowledge interchange rate (31%), team issues (29%), English domain (29%), geographical dimension (25%), defined of roles and responsibilities (25%), availability of human resource (22%), effective leadership (22%), degree of cooperation (22%), and software support tools (18%), as shown in Fig. 9.

Furthermore, the criteria most cited in the SLR are soft rather than hard skills, whereas the hard skills relate to the computer

[6]https://bit.ly/Criteria-list

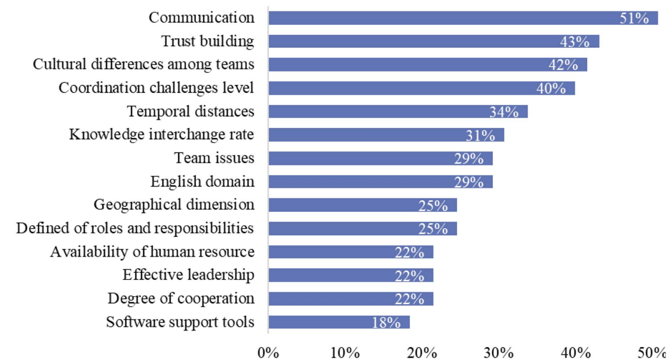

Fig. 9. Highly cited criteria.

Fig. 10. Word cloud made by the SLR documents abstracts.

science subject's bases, the soft skills are behavioral as social, organizational, teamwork, collaborative, communication, and project-based skills [90]. Hence, in the GSD context, here team members can be located anywhere, soft skills play a more crucial role than hard skills. This is primarily due to difficulty identifying and evaluating soft skills compared to hard skills during the worker selection process.

We assembled the word cloud using all the abstract words, as shown in Fig. 10. From this figure, we can indicate the analyzed data's compatibility. As we can see in the figure, the words with more evidence in the word cloud are: "software," "development," "gsd," "project,' "challenges," "factors," and "communication"; supporting our research's results when shown the "communication" as a most cited factor (51%), see Fig. 9.

Additionally, we apply the bibliometrix package in R and RStudio software to make a more consistent analysis, as shown in the following section.

4) Evolution of Scientific Production: The SLR database's descriptive analysis reveals that many authors published this research's theme but are not concentrating. The SLR database shows the document's average age is 4.09 years, the total number of authors is 189, the timespan is 2007:2022, and there are 45 sources.

The difference from other studies is the attributes (criteria) we collected from several perspectives, not for only one like as the challenges [91], or success factors [50], or barriers [28]. The criteria collected are aligned with the reality provoked by the pandemic of COVID-19 as we can see in the criteria "low quality of telecommunication bandwidth"(C247) [31], or "participation, acceptance, and learning incentive of innovative technology" (C154) [55], or "lifelong learning" (C289) [150]. Furthermore,

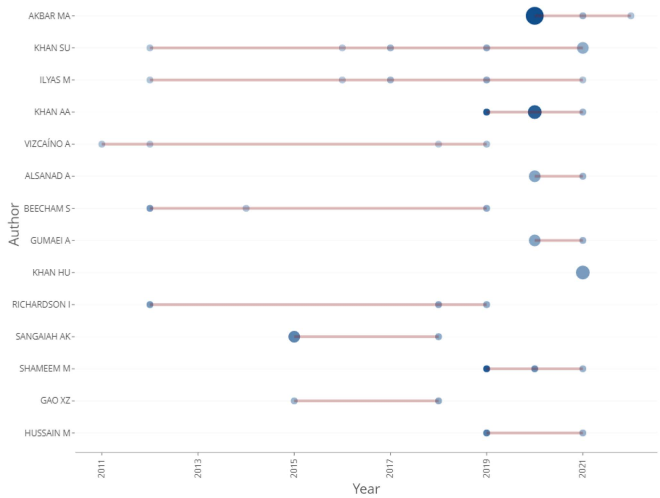

Fig. 11. Authors' production over time.

pass through the supply responsiveness as "behavioral skills at dealing with changing/ flexibility" (C116) [55], or "frequent information sharing among oversees practitioners" (C275) [89], [150], and, without forgetting the technical issue as "insufficiently defined or lack of conformance to shared practices across sites" (C225) [84], and "interfacing with different layers of development framework" (C120) [90].

Fig. 11 plots the authors' production (publications number and total citations per year) over time, as the bibliometric analysis proposed by Aria and Cuccurullo [110]. In this figure, we show the 14 most relevant authors in decrescent order, who are responsible for 44.6% of all production in the SLR database. As we can notice, there is no regular author in time. However, some authors have many publications, like Akbar with eight publications (12.3% of documents found) and Khan with five publications (7.7%), but they worked together in three opportunities [32], [38], [52]. Khan has six publications (9.2%), whereas five (7.7%) worked together with Ilyas [43], [45], [50], [53], [98]. Nevertheless, Viscaíno. worked alone with the authors of this SLR in four documents (6.2%). Alsanad and Gumaei have three publications (4.6%) together with Akbar [38], [89], [91]; as the author Shameem with the same number of publications jointly Khan [28], [29], [38]. The other authors in Fig. 11 have three or fewer publications.

As for the sources, the most cited were: IEEE Access, with eight publications; Journal of Software: Evolution and Process, with six publications; Information and Software Technology, and ACM International Conference Proceeding Series, with three publications during the analyzed period. All the other sources published had only one or two documents.

The publications by year are shown in Fig. 12, as we can see a publication concentration in the last three periods, considering that SLR finished on September 9th, 2022. Confronting Figs. 11 and 12, we can also notice the publications concentration in the last three years by the prominent authors.

The geographical allocation of the database (established in the first author's country) highlights the countries Pakistan with 13 documents (20%), China with 11 documents (16.9%), and India with seven documents (10.8%). The other countries are USA

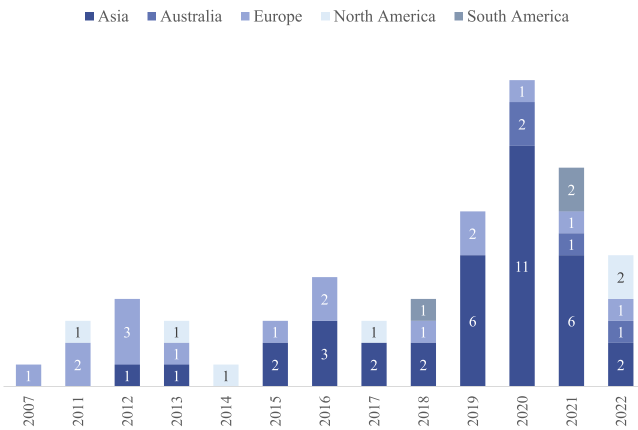

Fig. 12. Annual Scientific Production.

TABLE X
EVOLUTION OF CRITERIA CITATION

Criteria*	Year of publication												Total citation
	2007	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021/ 2022	
Communication	1	2	4	2	1	1	2	3	1	6	5	5	33
Trust building	1	1	2	2		2	2	1	1	4	7	5	28
Cultural differences among teams	1	1	4	1	1	1	2	2	1	6	3	4	27
Coordination challenges level	1	2	3	1		1	2	2	2	5	2	5	26
Temporal distances	1		3	1	1	1	1	1	1	5	3	4	22
Knowledge interchange rate			2	1		1	3	1	2	4	3	3	20
English domain	1	1	3	1	1		1		1	5	2	3	19
Team issues	1	1	3	1			1	1	1	4	4	2	19
Defined of roles and responsibilities	1		2			1	2			4	4	2	16
Geographical dimension		1	1	1	1	1	1		1	4	2	3	16
Degree of cooperation	1		1	1			2	1		1	3	3	13
Effective leadership	1	1	2				2	1		1	3	3	14
Availability of human resource	1		1				1	2		3	2	4	14
Software support tools			3	1				1	2	2	2	1	12

* Low concentration of the criterion. High concentration of the criterion.

and Australia, with four documents (6.15%); Spain, with three documents (4.6%); followed by Germany, Malaysia, Sweden, and Indonesia, with two documents each (3.1%). Other countries published only one document. The Asia continent concentrated more than half of the studies, and the other half dispersed into the other world regions. Fig. 12 shows the annual scientific production and regions over the years. Outlining, Asia concentrates 55%, Europe 25%, North America 9%, Australia 6%, and South America 5% of the publications.

Another relevant information is the evolution of the criteria citation by year, as shown in Table X. This table displays the citation intensity for each criterion, with the darker line indicating the year in which authors most frequently cited the criterion. Of the 14 main criteria, 93% (or 13) show a concentration of citations in the last four years. This evidence confirms the significance of this topic for the academic community, which has likely grown amid the disruption of global supply chains caused by the pandemic.

To evaluate the quality of the database, we utilized the Scopus source database to rank the relevant sources according to their classification. The database utilizes a quality index divided into four quartiles, namely Q1, Q2, Q3, and Q4. Journals in Q1 have the highest impact, while those in Q4 have the lowest impact. The result was Q1 with 46.2% of the sources, Q2 with 20.0%, Q3 with 10.8%, Q4 with 13.8%, and not available with 9.2% (six sources). We analyzed the sources without ranking, where the sources [53], [73] come from the two databases (Scopus and Web of Science). They are old conferences in the 19th edition

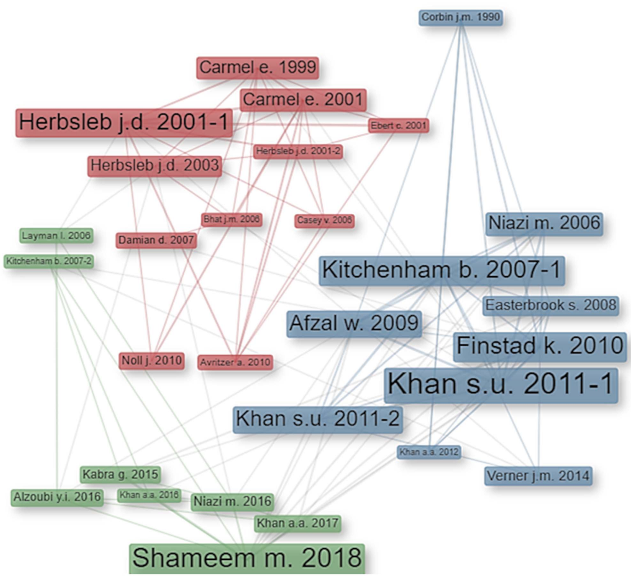

Fig. 13. Cocitation network.

and 42nd editions, respectively. As for the source, [40] is a discontinuous journal from the Scopus database. Nevertheless, despite these three sources, 66.2% of the sources belong to the first two quartiles, assuring the database's high quality.

In the following section, we show the cocitation network.

5) The Cocitation Network: We use the bibliometrix package [110] in R and RStudio software [105] to build the co-citation network figure and analysis. We separated the co-citation network in Fig. 13 as the type of study, the collaboration network, and at the top of the Figure is the older studies, and the bottom is the most recent. Thus, the method parameter was papers, automatic layout, the Louvain clustering algorithm, 30 numbers of nodes, remove isolated nodes as yes, and minimum edge as 2.

Therefore, using snowball searches [111], [112], we conducted a thorough examination of all cocitation network documents to search for new attributes or criteria that were not identified in the primary SLR documents. The objective was to enhance the completeness of the criteria database.

We start analyzing the authors in color blue in Fig. 13, and the GSD theme is directly related to 60% of the authors. Rising by the others, 40%, not related to GSD, where Corbin [151] and Finstad [152] made the studies concerning the research methodologies, Afzal [153] focused on software testing. Kitchenham [68], [154] dedicated to proposing a method for SLR in software engineering. The collaboration network is evident in this blue association with Niazi and Khan, where the first start analyzing critical success factors in the software process [155]. Next, Khan made an SLR identifying barriers and competitive factors in GSD [156] and [157]. Furthermore, in this blue group, Khan [158] proposed a framework to identify the communication risks, their causes, and effects during RCM in GSD systems. The blue group is concentrated on advanced economies with 50% in Europe, 30% in North America, and 20% in Asia.

The entire red group in Fig. 13 refers to the GSD subject. The most cited authors in the red group are Carmel and Herbsleb, where the first author wrote a book in 1999 [159] addressing the GSD team, and he made a paper approaching the distance issues in GSD [160]. In addition, Herbsleb made two documents in this group in 2001, a magazine paper addressing the effects of physical separation in GSD teams [161]. Also, he analyzed the delay and communication in GSD through an empirical study in the same-site and cross-site; he stated that similar tasks in cross-site take about two and one-half times as long to complete compared to same site [162]. In this group, we did not observe the collaboration network. However, we observed that 40% of the authors were dedicated to studying GSD teams managing themes, and the other themes were distance and requirements with 30%.

Finally, the green cocitation group in Fig. 13, with Shameem, who investigated the challenges for agile GSD using an online questionary and prioritized the category challenges through an analytic hierarchy process (AHP) [163], also worked together with Khan who has more two works in this green group. In both works, Khan investigated the software process improvement barriers [164], [165]. Moreover, Niazi [166] made a sturdy questionnaire to validate the management's challenges in GSD, and Alzoubi [167] investigated the communication challenges and the techniques used to overcome those challenges in Agile GSD. Only Kabra [168] did not study the GSD subject in this green group. Summarizing, the authors studied communication, challenges, and SPI barriers in the GSD context.

Afterward, however, we did not find out any new criteria after a complete reading of the cocitation network studies. Subsequently, we present the criteria-gathering process.

6) The Definition and the Criteria Gathering Process: In this section, we first present the criteria-gathering process based on the approach of the studies and authors (see Table VIII). Some authors, Sangaiah et al. [77], Richardson et al. [54], and Iqbal et al. [66], get the criteria from previous work. In many cases, the authors: Kamal et al. [37], Vizcaíno et al. [90], Bhatti and Ahsan [83], Sievi-Korte et al. [82], Baldwin and Damian [78], Šablis and Šmite [84], Imtiaz and Ikram [41], Hidayati et al. [81], and Shameem et al. [28] made a simple literature review or a SLR as the authors: Khan and Akbar [43], Akbar et al. [32], Ilyas and Khan [89], Lai et al. [86], and Hussain et al. [47] then after a survey to validate the methodology proposed. Ilyas and Khan [53] and Dumitriu et al. [74] only did a literature review, and Yaseen et al. [42], [60] and Defranco and Laplante [87] did a SLR. Finally, Kluge et al. [150] and Humayun and Cui [40] only surveyed to collect the criteria.

We summarize some documents from the SLR database. Hassan et al. [65] highlighted the current issues of GSD and provide policy recommendations to mitigate them. The article begins by defining the GSD issues very precisely. Then, they proposed the relationships between the factors that affect GSD and their impacts. After quantitative analyses to configure the actual problems, the authors' main contribution was to state policy recommendations for each GSD problem. Kuhrmann et al. [62] conducted a systematic mapping study of software process improvement (SPI) from a general perspective. They made an excellent overview of the metadata attributes and identified ten threats to SPI and Global Software Engineering (GSE) productivity. Lamersdorf et al. [48] conducted 19 interviews with experts from 14 U.S., Spain, and Indian companies. They point out 23 risk factors. Finally, Kroll et al. [59] investigated the existing empirical evidence about Follow the Sun (FTS). The authors' main contribution was the table that identifies and links the research topic and gaps by mapping the papers' research problems. FTS is a particular case of GSD, where software development occurs over a 24 h working day.

The definition of criteria was a weakness in many studies. The authors defined criteria entirely in 12.3% of the documents, partially in 38.5%, and did not define them in 49.2% of the documents. This lack of criteria description may interfere with the results, mainly when grouping them and utilizing questionnaire responses from researchers or professionals to prioritize the criteria. Only seven papers made a full criteria definition, namely: Nidhra et al. [39], Richardson et al. [77], Ammad et al. [31], Trinkenreich et al. [104], Ludwig et al. [61], Garro-Abarca et al. [96], and Bastidas et al. [95].

According to the SLR database, the researchers faced several challenges, including the identification, categorization, grouping, and scientific prioritization of the criteria. This section highlights the identification process, while the following section focuses on the authors' efforts to employ scientific approaches such as multicriteria decision-making (MCDM) methods to categorize, group, and prioritize the criteria.

7) MCDM and Multivariate Statistical Analysis Approaches: Multicriteria decision-making (MCDM) holds the decision-makers to rank or chooses the best alternatives based on several conflicting criteria. These methods represent 20% of the SLR database. The papers are very recent, wherein in 2022 and 2011, we had one document each. In 2020, we had four documents; in 2019 and 2018, with two documents; and in 2015, with three documents, demonstrating the approach's growth. We notice the spreading of the document's central theme. However, the first author's city concentrates on three countries, China, India, and Pakistan.

The SLR database has four documents that use the fuzzy Analytical Hierarchy Process (FAHP). The FAHP is an effective technique to address the vagueness and uncertainties in the expert's opinions. These documents follow the same structure: context, a literature review to collect the data, a questionnaire to validate the data, and FAHP to group and prioritize. For example, Gulzar et al. [51], as shown in Section 3.2, found 11 groups, and the "Trust" group was the more important group of situational factors in GSD. Khan et al. [29] investigated the software process improvement, identified 21 factors in the literature, grouped 21 success factors in 5 categories, and through a FAHP, demonstrated that "Project Administration" is the most critical category. Akbar et al. [38] analyzed the RCM activities, collected 23 success factors from SLR, made a questionnaire, grouped them into four categories, and used FAHP to determine that "Process" was the category most important. Then, Akbar et al. [52] now investigated cloud-based global software development. Following the same previous steps, they grouped into ten categories the motivators, and the most critical group was "integration with organizational IT infrastructure."

In sequence, we present in chronological order the other MCDM methods. Sangaiah et al. [54] applied a combined fuzzy DEMATEL and fuzzy TOPSIS approach to investigate the partnership quality and service climate aspects of GSD teams in the context of GSD project outcomes. They collected 18 criteria from their previous work and validated them through a case study with software company experts. According to the authors, the hybrid fuzzy DEMATEL–TOPSIS methods provide a more accurate approach to handling cognitive uncertainty arising from human perception in the group decision-making process. Thus, the essential criteria for evaluating GSD project outcome factors perceived by GSD teams is "project functionality toward client's business process."

Sangaiah et al. [80] made a comprehensive framework of the factors influencing KT effectiveness of GSD teams and by a Dempster–Shafer theory with a fuzzy DEMATEL approach to uncover the relative importance of the criteria and to prioritize.

Gopal et al. [55] analyzed the knowledge transfer effectiveness. From previous and related works, the authors get 25 evaluation criteria. First, they use a fuzzy DEMATEL approach to determine the criteria' priority weights. Second, a fuzzy MCDM was applied to identify the rank and significance of the attributes. The case results indicate that knowledge, team, and technology are the most significant impact on evaluating the knowledge transfer effectiveness of GSD teams in the context of GSD project outcome.

Khan et al. [45], based on their two previous works (SLR), collected the challenges and best practices. They chose six problems and surveyed 42 experts to confirm the SLR findings. They then developed a communication and coordination challenges mitigation model based on the capability maturity model integration. Finally, they applied the fuzzy multiattribute decision-making (FMADM) approach to forecasting the possibility of a successful offshore software development outsourcing relationship.

Goyal and Gupta [64] evaluated the team selection on GSD. They collected the attributes of team members through a performance assessment/evaluation system of the organization. Thus, they identified 19 criteria to perform a correct choice of team members underneath GSD and subsequently classified them using intuitionistic fuzzy for the aggregated opinion of several experts. They used IFMM (intuitionistic fuzzy Muirhead Mean) to assemble the intuitionistic criteria.

Nurrahman et al. [99] explored the influencing characteristics in choosing software development methodology and raking them for the online GE assignment. Using the standard AHP, the authors state that the requirement is of the most heightened importance when developing software in the GE, followed by user involvement, documentation, and personnel.

Through an SLR, Rafi et al. [103] identified 16 situation factors of DevOps. Then mapped into DevOps basic principles and confirmed with industrial practitioners by performing a questionnaire survey. Moreover, they applied the PROMETHEE-II technique to explore the factors' logical relationships and ranks.

We found two documents that used multivariate statistical analysis, another scientific method, to investigate the groups. Sundararajan et al. [49] used principal component analysis (PCA), and Chatzipetrou et al. [73] used a hierarchical cluster analysis (HCA). Based on the literature, Sundararajan et al. [49] consolidated a list of risks associated with software development. From that, the authors surveyed and collected 145 responses available for analysis. Then, the authors finalized the list with seven risk factors and validated them with multivariate analysis. Structural equation modeling (SEM) is a multivariate statistical method with an affirmative approach to analyzing a structural theory. The SEM allows the researcher to model incomprehensible complex relationships with other multivariate techniques [49].

Chatzipetrou et al. [73] empirically studied 65 people in a GSD environment to prioritize 24 software quality characteristics. They use hierarchical cluster analysis (HCA) to prioritize the data. HCA is a multivariate statistical technique that recognizes relatively homogeneous clusters of individual cases founded on their values of a standard set of variables [73]. It also uses this value to describe them. They concluded that the stakeholders create groups of aligned understanding of preferences according to personal and cultural views, preferably than their functions in software development.

To date, the results in the GSD domain have been contradictory or inadequate. The cited documents provide a variety of results, highlighting the diverse interpretations of various criteria. As noted by Gulzar et al. [51], researchers have shown interest in multiple aspects of criteria interpretation. For instance, some investigators have acknowledged the significance of cultural distinctions as they greatly influence GSD, while others have not considered culture significant.

In the following section, we show the criteria clustering results.

B. NLP and Clustering Results

In this section, we present the employed algorithms, the clusters, the cluster group of the clusters formed, and its mind map.

1) Clustered Criteria Algorithm: The clustered criteria algorithm observed three steps: SBERT, k-means clustering, and a cluster of the cluster's mind map.

First, we select the Sentence-BERT (SBERT) pretrained BERT network, with the model name "all-mpnet-base-v2" due to its high performance in semantic search.[7] Then, we compute the sentence embeddings in a Python framework. Hence, we used the criterion definitions cleaned from the reference numbers shown in the worksheet Criteria Database in SI-file by the column "Final Criteria definition (for NLP)."

Second, we apply the k-means clustering approach in a Python framework. We obtained from SLR 319 criteria; however, we typically apply clustering to a higher magnitude of elements. Therefore, making clusters of sentences based on the researcher's opinions (such as an Affinity Diagram) could not represent the most acceptable solution. Hence, we use the *elbow* method to visualize the optimal k (number of clusters), as shown in Fig. 14. The curve is flat without a noticeable *elbow*, but the algorithm returns 25 clusters of the criteria.

Therefore, as Schubert [148] stated, we employ an exploratory approach that can yield attractive solutions varying from 16 to 25 initial clusters. Thus, we executed the algorithm ten times. After an exploratory study, and for better comprehension to practitioners, the adequate number of criteria clusters was 25. Furthermore, we built the word cloud for each cluster to help create cluster names. These algorithms and the word clouds were present in the link.[8]

[7] [Online]. Available: https://www.sbert.net/docs/pretrained_models.html
[8] [Online]. Available: http://bit.ly/3WGtKCP

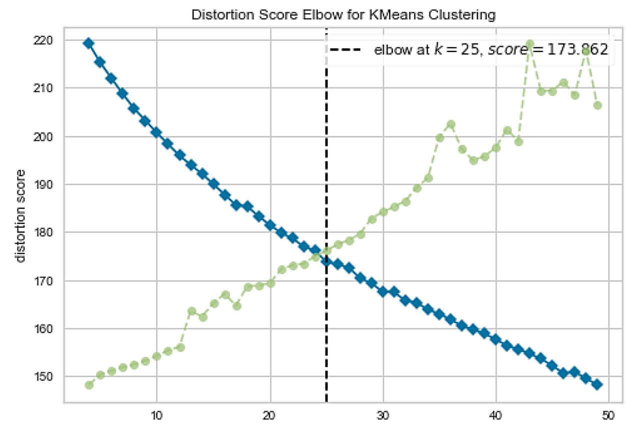

Fig. 14. Elbow score for k-means criteria clustering.

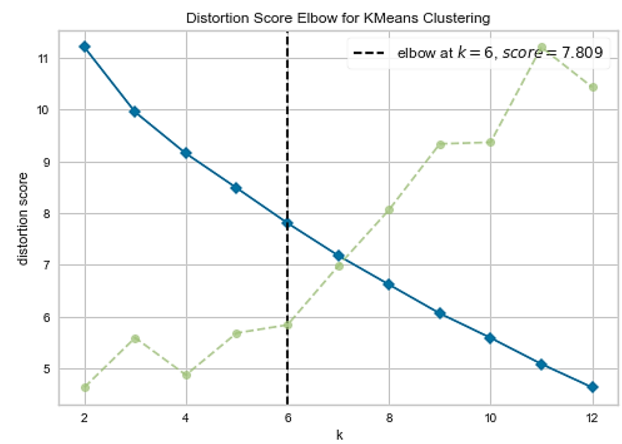

Fig. 15. Elbow score for k-means criteria clustering.

Finally, we displayed the 25 clusters, the cluster group of the clusters formed, and its mind map in the following section.

2) Cluster of the Clusters' Mind Map: Once we had completed the 25 clusters of the 319 criteria, the next task was developing an innovative and responsive model to present the data. Then, we compiled the 25 clusters in a worksheet and repeated the same clustering algorithm. We also use the *elbow* method to visualize the optimal k, as shown in Fig. 15.

Similarly, we utilize an exploratory approach ranging from four to six initial clusters. Thus, in this exploratory study, we ran the algorithm three times, and for better understanding of practitioners, the suitable number of criteria clusters was six.

Consequently, we created a cluster group word cloud to support creating cluster group names. These algorithms and the cluster group word clouds were present in the link.[9]

Fig. 10 displays the composition of cluster groups formed in the Pareto chart created using Minitab. The chart reveals the highest criteria composition in the following order:

Fig. 16 displays the composition of cluster groups formed in the Pareto chart created using Minitab. The chart reveals the highest criteria composition in the following order: Team communication (142 criteria), management (70 criteria), software

[9] [Online]. Available: http://bit.ly/3I2drfr

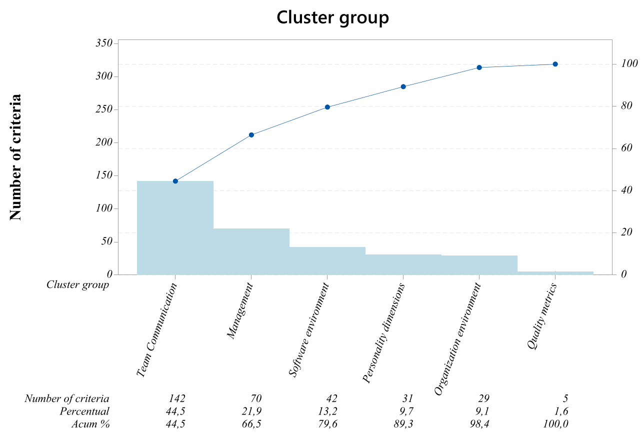

Fig. 16. Cluster group composition.

TABLE XI
CLUSTER 2: TEAM ORGANIZATION AND ATTITUDE—1/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C029	Contribution to team effort	3 (5%)	XXXVI
C037	Contributing to discussions	1 (2%)	XXXVI
C039	Communicate clearly with team	1 (2%)	XXXVI
C058	Continuous organisational support	4 (6%)	XXXVII
C118	Problem solving	3 (5%)	XXXVIII
C141	Participation and support to solve issues	5 (8%)	XXXIX
C142	Persistent, conscientious responsiveness information of teams	2 (3%)	XXXIX
C152	Brainstorming actions for organizations	1 (2%)	XXXIX
C153	Flexibility among teams	2 (3%)	XXXIX
C202	Capability to adopt team members	1 (2%)	XL
C217	Team rewards and recognitions	1 (2%)	XLI
C218	Employee facilitation	3 (5%)	XLI
C236	Team member's attitude	1 (2%)	XLI
C273	Charismatic leadership	1 (2%)	XLII
C281	Experienced staff	2 (3%)	XLII
C285	Organizational commitments	1 (2%)	XLIII
C316	Team Empowerment	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

environment (42 criteria), personality dimensions (31 criteria), organization environment (29 criteria), and quality metrics (5 criteria).

It is necessary to highlight that the number of times each criterion was mentioned in the SLR database did not influence the grouping algorithm since the citation code was removed from the criterion definition. Additionally, although the *k*-means clustering algorithm may generate different clusters for each run, we conducted 300 iterations to obtain more consistent clusters. Moreover, the sentence embeddings generated by the SBERT algorithm were highly reliable, as evidenced by consistent cluster results obtained from multiple algorithm runs.

Finally, the cluster and cluster groups composed make sense. For this reason, we also created a mind map of the cluster groups for a better data presentation, as shown in Fig. 17. Moreover, in an online view, we suggest seeing the mind map first, then clicking on the respective cluster table. Then, to see the criterion defined in the cluster table, click on its table number. Thereby, in the criteria table with definitions, in the table footer, click on the number of Fig. 17 to repeat this process.

The first cluster group displayed is team communication, which comprises team organization and attitude (Table XI), stakeholders (Table XII), communication (Table XIII), team skills (Table XIV), task responsibilities (Table XV), team relationship (Table XVI), conflict management (Table XVII), and knowledge transfer (Table XVIII). This cluster group represents 44.5% of the total criteria in the SLR database. Thus, this demonstrates the importance of the communication criterion (C001), with 51% citation in the SLR database, as pointed out in Fig. 9. Furthermore, all groups formed are linked, even the cluster group stakeholders, by the criteria communicate clearly and civilly with stakeholders (C041 and C042) and stakeholder engagement (C179).

TABLE XII
CLUSTER 3: STAKEHOLDERS—2/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C040	Communicate civility with team	1 (2%)	XXXVI
C041	Communicate clearly with stakeholders	1 (2%)	XXXVI
C042	Communicate civility with stakeholders	1 (2%)	XXXVI
C128	Globally compete to market	2 (3%)	XXXIX
C151	Understanding over the client's business process environment	6 (9%)	XXXIX
C177	Stakeholder: Client	2 (3%)	XL
C178	Stakeholder: Relationship	3 (5%)	XL
C179	Stakeholder engagement	3 (5%)	XL
C181	Stakeholder Performance Domain	1 (2%)	XL
C182	Stakeholder: problem domain	2 (3%)	XL

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XIII
CLUSTER 5: COMMUNICATION—3/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C001	Communication	33 (51%)	XXXVI
C003	Cultural differences among teams	27 (42%)	XXXVI
C004	Temporal issues	22 (34%)	XXXVI
C005	Fear impact	2 (3%)	XXXVI
C006	Employee Satisfaction	5 (8%)	XXXVI
C020	Relevant information disclosure	4 (6%)	XXXVI
C024	Technical support	3 (5%)	XXXVI
C025	Communication Tools	6 (9%)	XXXVI
C053	Response/ feedback online	4 (6%)	XXXVII
C060	Task synchronization	6 (9%)	XXXVII
C062	Geographical dimension	16 (25%)	XXXVII
C063	Organizational dispersion	7 (11%)	XXXVII
C076	Relationship between person at different sites	4 (6%)	XXXVII
C103	Task updating	4 (6%)	XXXVIII
C186	Working and workplace atmosphere	1 (2%)	XL
C191	Tools and technology: process selection	3 (5%)	XL
C206	Face to face meeting	6 (9%)	XL
C210	Technical Infrastructure	6 (9%)	XLI
C235	Socio-culture distance	2 (3%)	XLI
C238	Cost and logistics of meetings	1 (2%)	XLI
C239	Effort to initiate contact	1 (2%)	XLI
C240	Time overlapping	2 (3%)	XLI
C241	Communication frequency	5 (8%)	XLI
C242	Detailed level of communication	2 (3%)	XLI
C244	Domain of manager's opinion	1 (2%)	XLI
C245	Connectivity issues	2 (3%)	XLI
C246	Degree of infrastructure	6 (9%)	XLII
C247	Quality of telecommunication bandwidth	1 (2%)	XLII
C262	Interpersonal relationships skills	3 (5%)	XLII
C275	Frequent information sharing	5 (8%)	XLII
C279	Use of English for communication	1 (2%)	XLII
C280	Informal communication	4 (6%)	XLII
C307	Degree of communication concreteness	2 (3%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XIV
CLUSTER 9: TEAM SKILLS—4/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C002	English domain	19 (29%)	XXXVI
C012	Defined of roles and responsibilities	16 (25%)	XXXVI
C013	Technical requirements	2 (3%)	XXXVI
C026	Proficiency in a programming language	6 (9%)	XXXVI
C027	Experience in similar projects	4 (6%)	XXXVI
C045	Comprehension ability	2 (3%)	XXXVII
C052	Skilled human resources	5 (8%)	XXXVII
C109	Expert area (prior experience)	2 (3%)	XXXVIII
C110	Scrum expertise	2 (3%)	XXXVIII
C149	Pilot knowledge between teams	2 (3%)	XXXIX
C193	Tools and technology: management decision	2 (3%)	XL
C200	Team size/ structure	9 (14%)	XL
C255	Specialty ability of the teams	1 (2%)	XLII
C263	Reasoning skills	2 (3%)	XLII
C265	Communication skills in a second language	3 (5%)	XLII
C304	Total number of technical skills (one employee)	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

Fig. 17. What matters in hiring professionals for GSD—Cluster of the clusters' mind map.

The second cluster group shown is personality dimensions, as shown in Tables XIX–XXI. This cluster group better illustrates how robust the clustering algorithm applied for sentence embeddings is. Each of the three clusters in this group makes much sense. We highlight the cluster gender segregation (Women) [11], [104], one criteria group that has few investigations for researchers, but usually, we can notice some of this criterion from the practitioners, as the Work–Life Balance Issues (C296) and Pay inequality between genders (C301). Furthermore, in Cluster 19, some new criteria, such as Lifelong Learning (C289) and Religion and political attitudes (C124), are implicated in the GSD context and may provoke changes in the schedule plan.

The third cluster group shown is Quality Metrics, as shown in Table XXII, the only cluster group formed by a single cluster with five criteria merely. Moreover, this cluster group stands for only 1.6% of all criteria in the SLR database; see Fig. 16. The most cited criterion in this cluster is Metrics (C162), with four citations, concerns automated, semiautomated, and manual metrics in risk and quality evaluations.

TABLE XV
CLUSTER 10: TASK RESPONSIBILITIES—5/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C012	Defined of roles and responsibilities	16 (25%)	XXXVI
C017	Coordination challenges level	26 (40%)	XXXVI
C018	Transparency of roles and responsibilities	6 (9%)	XXXVI
C030	Accomplishment of assigned responsibilities	2 (3%)	XXXVI
C031	Task efficiency	2 (3%)	XXXVI
C032	Tasks effectiveness	1 (2%)	XXXVI
C046	Assignment of roles and responsibilities	3 (5%)	XXXVII
C078	Criticality of the task	1 (2%)	XXXVII
C079	Complexity of the task	1 (2%)	XXXVII
C080	Degree of Task formality description	1 (2%)	XXXVII
C139	Workload	4 (6%)	XXXIX
C140	Task Size	1 (2%)	XXXIX
C305	Degree of task information	2 (3%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XVI
CLUSTER 14: TEAM RELATIONSHIP—6/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C008	Degree of cooperation	14 (22%)	XXXVI
C014	Effective Partitioning	2 (3%)	XXXVI
C021	Team issues	19 (29%)	XXXVI
C051	Strong team relationship	7 (11%)	XXXVI
C077	Common working experience	2 (3%)	XXXVII
C082	Degree of collaborative task coupling	2 (3%)	XXXVII
C086	Number of involved sites	1 (2%)	XXXVIII
C088	Learning curve	2 (3%)	XXXVIII
C090	Vision for the end product	1 (0%)	XXXVIII
C108	Cross-functional teams	3 (5%)	XXXVIII
C135	Task site dependency	2 (3%)	XXXIX
C146	Mutual coordination among team members (managerial practices)	3 (5%)	XXXIX
C174	Inter-team culture (NCASN)	1 (2%)	XL
C201	Team cohesion	4 (6%)	XL
C213	Productivity	1 (2%)	XLI
C230	Task allocation	4 (6%)	XLI
C243	Mutual understanding	1 (2%)	XLI
C251	knowledge creation ability among the teams	3 (5%)	XLII
C253	Cooperation and competition within the teams' to fulfill the goals	2 (3%)	XLII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XVII
CLUSTER 17: CONFLICT MANAGEMENT—7/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C010	Effective leadership	14 (22%)	XXXVI
C011	Project failure risk	5 (8%)	XXXVI
C064	Turnover (team/staff)	2 (3%)	XXXVII
C074	Availability of human resources	14 (22%)	XXXVII
C087	Time pressure	4 (6%)	XXXVIII
C091	Overloading of key personnel	1 (2%)	XXXVIII
C115	Conflict management	5 (8%)	XXXVIII
C116	Flexibility	3 (5%)	XXXVIII
C117	Handling stress	1 (2%)	XXXVIII
C130	Management commitment	4 (6%)	XXXIX
C136	Personal availability	1 (2%)	XXXIX
C192	Project management performance	2 (3%)	XL
C203	Team experience	5 (8%)	XL
C208	Labor cost	2 (3%)	XL
C209	Human related problems	1 (2%)	XLI
C220	Project instability	2 (3%)	XLI
C234	Handling soft issues	1 (2%)	XLI
C248	Lack of ICT and technological cohesion	4 (6%)	XLII
C278	Financial maturity	2 (3%)	XLII
C283	Budget constraints	2 (3%)	XLII
C310	Lack of long-term planning	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XVIII
CLUSTER 21: KNOWLEDGE TRANSFER—8/8 [TEAM COMMUNICATION CLUSTER GROUP—1/6]

Code	Criteria	Cited*	Table**
C009	Precise cost estimation	10 (15%)	XXXVI
C016	Knowledge interchange rate	20 (31%)	XXXVI
C023	Software support tools	12 (18%)	XXXVI
C066	New vendor relationship	1 (2%)	XXXVII
C067	Updated Knowledge transfer documents	1 (0%)	XXXVII
C068	Knowledge Codifiability	1 (2%)	XXXVII
C144	Capacity to absorb technical and business knowledge	1 (2%)	XXXIX
C145	Understanding the process	5 (8%)	XXXIX
C148	Knowledge incentive toward client business process	3 (5%)	XXXIX
C154	Learning of innovative technology	4 (6%)	XXXIX
C196	Knowledge assets	1 (2%)	XL
C254	Explicit and standard communication pattern for knowledge transfer effectiveness	2 (3%)	XLII
C257	Assessment of teams knowledge transfer effectiveness	2 (3%)	XLII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XIX
CLUSTER 7: SCIENTIFIC ATTITUDE—1/3 [PERSONALITY DIMENSIONS CLUSTER GROUP—2/6]

Code	Criteria	Cited*	Table**
C033	Independence of thought and action	2 (3%)	XXXVI
C035	Scientific attitude	1 (2%)	XXXVI
C268	Computer anxiety (personality dimensions)	1 (2%)	XLII
C294	Lack of conviction issues	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XX
CLUSTER 13: GENDER SEGREGATION (WOMEN)—2/3 [PERSONALITY DIMENSIONS CLUSTER GROUP—2/6]

Code	Criteria	Cited*	Table**
C295	Gender preference and segregation	3 (5%)	XLIII
C296	Work-Life Balance Issues (Women)	1 (2%)	XLIII
C297	Benevolent Sexism (Women)	1 (2%)	XLIII
C298	Lack of Recognition (Women)	1 (2%)	XLIII
C299	Lack of Peer Parity (Women)	1 (2%)	XLIII
C300	Impostor phenomenon (Women)	1 (2%)	XLIII
C301	Pay inequality between genders (Women)	1 (2%)	XLIII
C302	Prove-it Again (Women)	1 (2%)	XLIII
C303	Maternal Wall (Women)	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XXI
CLUSTER 19: PERSONALITY DIMENSIONS—3/3 [PERSONALITY DIMENSIONS CLUSTER GROUP—2/6]

Code	Criteria	Cited*	Table**
C034	Creativity in approach to problem solving	1 (2%)	XXXVI
C036	Determination and effort	1 (2%)	XXXVI
C038	Accepting criticism gracefully (personality dimensions)	1 (2%)	XXXVI
C113	Analytical thinking	1 (2%)	XXXVIII
C114	Time management	3 (5%)	XXXVIII
C124	Religion and political attitudes	5 (8%)	XXXVIII
C252	Ability to solve their professional problems	1 (2%)	XLII
C259	Benevolence	1 (2%)	XLII
C261	Accountability	1 (2%)	XLII
C267	Extroversion (personality dimensions)	1 (2%)	XLII
C269	Self-control (personality dimensions)	2 (3%)	XLII
C270	Sensitivity (personality dimensions)	1 (2%)	XLII
C271	Emotional stability (personality dimensions)	1 (2%)	XLII
C272	Conscientiousness (personality dimensions)	1 (2%)	XLII
C274	Age	1 (2%)	XLII
C289	Lifelong learning	1 (2%)	XLIII
C306	Degree of personal information	1 (2%)	XLIII
C308	Degree of affective intensity	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XXII
CLUSTER 12: QUALITY METRICS—1/1 [QUALITY METRICS CLUSTER GROUP—3/6]

Code	Criteria	Cited*	Table**
C121	Code coverage concepts and tools	2 (3%)	XXXVII
C162	Metrics	4 (6%)	XXXVIII
C216	Quality of test	1 (2%)	XL
C317	Metrics to assess risk-based testing	1 (2%)	XLIII
C318	Metrics to assess risk-based testing activities (time)	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

TABLE XXIII
CLUSTER 1: AGILE AND TRAINING—1/6 [MANAGEMENT CLUSTER GROUP—4/6]

Code	Criteria	Cited*	Table**
C048	Team training and monitoring	7 (11%)	XXXVII
C111	Scrum hours	1 (2%)	XXXVIII
C112	Number os sprints	1 (2%)	XXXVIII
C156	Advance and Uniform Development Environment and Training	5 (8%)	XXXIX
C282	Agile team training	2 (3%)	XLII
C286	Scaling tools and standards	1 (2%)	XLIII
C319	Training of DevOps activities	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.

The fourth cluster group shown is Management, comprising agile and training (Table XXIII), project requirements (Table XXIV), component integration (Table XXV), process management (Table XXVI), software changes (Table XXVII), and change requirement management (Table XXVIII). Nevertheless, with 21.9% of all criteria, this cluster group is the second in terms

TABLE XXIV
CLUSTER 8: PROJECT REQUIREMENTS—2/6 [MANAGEMENT CLUSTER GROUP—4/6]

Code	Criteria	Cited*	Table**
C019	Reporting requirement	10 (15%)	XXXVI
C085	Stable requirements	7 (11%)	XXXVIII
C104	Quality assurance procedure	7 (11%)	XXXVIII
C125	Updated requirements	6 (9%)	XXXVIII
C134	Site characteristics	1 (2%)	XXXIX
C143	Project requirements	5 (8%)	XXXIX
C147	Clear objective	1 (2%)	XXXIX
C150	Project functionality toward client's business process	2 (3%)	XXXIX
C161	Process, Data and Product's Components	3 (5%)	XXXIX
C180	Stakeholder: requirements	2 (3%)	XL
C187	Project: Characteristics	1 (2%)	XL
C188	Requirement estimation	1 (2%)	XL
C195	Tools and technology: testing accuracy	2 (3%)	XL
C205	Global project management issues	4 (6%)	XL
C207	User involvement	2 (3%)	XL
C214	Project methodology (approach, mentoring)	4 (6%)	XLI
C215	Quality of build	1 (2%)	XLI
C221	Software quality control	3 (5%)	XLI
C237	Customer relationship	5 (8%)	XLI
C250	Communication of customer requirements	2 (3%)	XLII
C284	Project scope	2 (3%)	XLII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXV
CLUSTER 11: COMPONENT INTEGRATION—3/6] [MANAGEMENT CLUSTER GROUP—4/6

Code	Criteria	Cited*	Table**
C061	Software testing methods	9 (14%)	XXXVII
C069	Proper documentation	6 (9%)	XXXVII
C070	Compatibility of data	6 (9%)	XXXVII
C072	Similar programming languages	3 (5%)	XXXVII
C089	Integration plan	4 (6%)	XXXVIII
C105	Incremental integration	2 (3%)	XXXVIII
C155	Component or Unit Testing prior to integration	2 (3%)	XXXIX
C163	Specific Integration Timing	1 (2%)	XXXIX

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXVI
CLUSTER 16: PROCESS MANAGEMENT—4/6 [MANAGEMENT CLUSTER GROUP—4/6]

Code	Criteria	Cited*	Table**
C022	Process Management	6 (9%)	XXXVI
C056	Formal standard and procedures	4 (6%)	XXXVII
C081	Process phase (lifecycle)	1 (2%)	XXXVII
C131	Software Process improvement - Consultancy	2 (3%)	XXXIX
C132	Process improvement evaluation	2 (3%)	XXXIX
C133	Process improvement standards and procedures	2 (3%)	XXXIX
C137	Process ownership	3 (5%)	XXXIX
C249	Uniform processes	2 (3%)	XLII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXVII
CLUSTER 18: SOFTWARE CHANGES—5/6 [MANAGEMENT CLUSTER GROUP—4/6]

Code	Criteria	Cited*	Table**
C057	Change acceptability	10 (15%)	XXXVII
C065	Degree of novelty	6 (9%)	XXXVII
C092	Consistent data	1 (0%)	XXXVIII
C106	Regular deliveries	4 (6%)	XXXVIII
C107	Use of modular approach	3 (5%)	XXXVIII
C122	Refactoring concepts	1 (2%)	XXXVIII
C123	Code-smell concepts	1 (2%)	XXXVIII
C126	Change impact analysis in all sites	3 (5%)	XXXVIII
C129	Progress measure in distributed sites	4 (6%)	XXXIX
C157	Continuous integration	3 (5%)	XXXIX
C212	Effort and cost estimation for change	1 (2%)	XLI
C315	Polymorphic design	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXVIII
CLUSTER 23: CHANGE REQUIREMENT MANAGEMENT—6/6 [MANAGEMENT CLUSTER GROUP—4/6]

Code	Criteria	Cited*	Table**
C047	Transparency of Vision and goal	8 (12%)	XXXVII
C049	Geographically distributed CCB (change control block)	2 (3%)	XXXVII
C050	Resistance management of changing	1 (2%)	XXXVII
C055	Process awareness	6 (9%)	XXXVII
C083	Degree of Business Process maturity	5 (8%)	XXXVIII
C102	Contract management	3 (5%)	XXXVIII
C127	Management support	3 (5%)	XXXVIII
C159	Configuration management	3 (5%)	XXXIX
C165	Organization: strategies	1 (2%)	XXXIX
C189	Collaboration, communication and coordination: inter-team, inter-site	10 (15%)	XL
C190	Collaboration, communication and coordination: cross-boundary	7 (11%)	XL
C204	Requirement management	5 (8%)	XL
C211	Infrastructure	3 (5%)	XLI
C277	Client and vendor organizational management commitment	2 (3%)	XLII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXIX
CLUSTER 0: SOCIAL AND GEOLOGICAL - 1/3 [ORGANIZATION ENVIRONMENT CLUSTER GROUP - 5/6]

Code	Criteria	Cited*	Table**
C043	Collaborative work friendly	2 (3%)	XXXVI
C059	Frequency of social events	2 (3%)	XXXVII
C175	Social facilities	1 (2%)	XL
C176	Social interaction	2 (3%)	XL
C184	Climatic condition	2 (3%)	XL
C185	Geological condition	1 (2%)	XL
C258	Communality	1 (2%)	XLII
C260	Internalised norms	1 (2%)	XLII
C264	Communication protocols and customs	1 (2%)	XLII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXX
CLUSTER 15: TRUST - 2/3 [ORGANIZATION ENVIRONMENT CLUSTER GROUP - 5/6]

Code	Criteria	Cited*	Table**
C007	Trust building	28 (43%)	XXXVI
C119	Diplomacy	1 (2%)	XXXVIII
C197	Trust: among team members	3 (5%)	XL
C198	Trust: cross-boundary	1 (2%)	XL
C199	Trust: confidence in the company and leadership and other stakeholders	2 (3%)	XL
C256	Mediating role knowledge transfer	1 (2%)	XLII
C266	Ability to motivate others and create trust	3 (5%)	XLII
C293	Eminence Education	2 (3%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXXI
CLUSTER 20: ORGANIZATION - 3/3 [ORGANIZATION ENVIRONMENT CLUSTER GROUP - 5/6]

Code	Criteria	Cited*	Table**
C044	Culture of leadership	9 (14%)	XXXVII
C164	Organization: resource	1 (2%)	XXXIX
C166	Organization: standard	1 (2%)	XXXIX
C167	Organization: culture	5 (8%)	XXXIX
C168	Organization: politics	1 (2%)	XXXIX
C169	Organization: practices	1 (2%)	XXXIX
C170	Organization: regulations	1 (2%)	XL
C171	Organization: environment	1 (2%)	XL
C172	Organization: structure	2 (3%)	XL
C173	Organization: size	1 (2%)	XL
C183	Stakeholder Attitude	1 (2%)	XL
C287	Error management culture	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

of criteria composition, as shown in Fig. 16. Researchers have satisfactorily explored these topics. Also, when looking at the criteria description, all the clusters in that group are linked.

The fifth cluster group shown is the organization environment, as shown in Tables XXIX—Social and Geological, XXX—Trust, and XXXI—Organization. Regarding criteria number, this cluster group has a similar importance as the personality dimensions, with 9.1% versus 9.7%, respectively. Finally, we underline cluster 15 Trust, which has the second most cited criterion, trust building (see Fig. 9), an important subject investigated in SLR [51]. This group resides in this cluster group instead of team management or personality dimensions. However, if we compare the criteria definition, we may consider the relationship between the criteria like social interaction (C176), communality (C258), frequency of social events (C059), and organization: environment (C171) that are strictly correlated with trust.

Finally, the last cluster group, but the third in terms of importance by the number of criteria (13.2%), is the software environment, comprised of Green software development (Table XXXII),

TABLE XXXII
CLUSTER 4: GREEN SOFTWARE DEVELOPMENT - 1/4 [SOFTWARE ENVIRONMENT CLUSTER GROUP - 6/6]

Code	Criteria	Cited*	Table**
C028	Use of software tools	1 (2%)	XXXVI
C120	Interfacing with different layers of development framework	3 (5%)	XXXVIII
C276	Requirements elicitation techniques	1 (2%)	XLII
C292	Reuse ability	1 (2%)	XLIII
C309	Limited support for reusability	1 (2%)	XLIII
C312	E-waste minimization	1 (2%)	XLIII
C313	Green and sustainable management of product life cycle	1 (2%)	XLIII
C314	Minimal reengineering	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXXIII
CLUSTER 6: DATA ENVIRONMENT - 2/4 [SOFTWARE ENVIRONMENT CLUSTER GROUP - 6/6]

Code	Criteria	Cited*	Table**
C054	Requirement and data traceability	9 (14%)	XXXVII
C093	Misspelling in data entry	1 (0%)	XXXVIII
C094	Missing information	1 (0%)	XXXVIII
C095	Data Harmonization	2 (3%)	XXXVIII
C096	Data visualization tools	1 (0%)	XXXVIII
C097	Data aggregation	3 (5%)	XXXVIII
C098	Measuring provenance of data	1 (0%)	XXXVIII
C099	Storage of transition logs	1 (2%)	XXXVIII
C100	Analyze Data in Real Time	3 (5%)	XXXVIII
C101	New visualization techniques and their assessments	1 (2%)	XXXVIII
C194	Tools and technology: defect occurrence	1 (2%)	XL
C288	Handling of data	1 (2%)	XLIII
C290	Legislation and regulation with cloud provider	1 (2%)	XLIII
C291	Choose the right cloud service provider	1 (2%)	XLIII
C311	Efficient utilization of time and computing resources	1 (2%)	XLIII

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXXIV
CLUSTER 22: ARCHITECTURAL PRACTICES - 3/4 [SOFTWARE ENVIRONMENT CLUSTER GROUP - 6/6]

Code	Criteria	Cited*	Table**
C071	Appropriate architecture	6 (9%)	XXXVII
C219	Alignment between architectural decisions to organization structure	2 (3%)	XLI
C222	Align architecture with organization arrangement	2 (3%)	XLI
C223	knowledge management practices	3 (5%)	XLI
C224	Communicate architectural decisions to all stakeholders	1 (2%)	XLI
C225	Conformance to share practices	2 (3%)	XLI
C226	Standardize architectural practices	1 (2%)	XLI
C228	Architectural design practices	1 (2%)	XLI
C229	Architecting modeling techniques	1 (2%)	XLI
C231	Architecture-based task allocation	2 (3%)	XLI
C232	Compliance to processes	6 (9%)	XLI
C233	Governance implemented	4 (6%)	XLI

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

TABLE XXXV
CLUSTER 24: COMPONENT INTERFACE - 4/4 [SOFTWARE ENVIRONMENT CLUSTER GROUP - 6/6]

Code	Criteria	Cited*	Table**
C073	Product selection and customization (off the shelf)	1 (2%)	XXXVII
C075	Proper component interfaces	1 (2%)	XXXVII
C084	Product size	3 (5%)	XXXVIII
C138	Component dependency	1 (2%)	XXXIX
C158	Interface Compatibility	1 (2%)	XXXIX
C160	Components evaluation	1 (2%)	XXXIX
C227	Identifying dependencies on architectural design decision	2 (3%)	XLI

*Times and percentage that the criteria were cited. **Table with the defined criteria. See all the clusters in Fig. 17.*

data environment (Table XXXIII), architectural practices (Table XXXIV), and component interface (Table XXXV). We must highlight cluster 4 Green Software Development [98], with criteria such as E-waste minimization (C312) and Green and sustainable management to product life cycle (C313), demonstrating the current social responsibility worldwide.

Summarizing all 25 clusters, we underline the top five with the most criteria. Thus, communication cluster 5 (Table XIII) has 33 criteria, the most critical cluster and criteria (C001), as pointed out in the SLR, followed by 21 criteria, conflict management cluster 17 (Table XVII), and Project requirements cluster 8 (Table XXIV). Moreover, the Team relationship cluster 14 (Table XVI) obtained 19 criteria, and the personality dimensions cluster 19 (Table XXI) obtained 18 criteria. Nonetheless, we cannot infer that these top five clusters, in terms of importance based only on the SLR and the clustering algorithm, may be necessary to add the practitioners' opinions to underline or, at least, create a relation map with all the clusters formed. With the cluster of criteria presented, professionals must decide the most required clusters to evaluate the candidate's profile for the open position.

By examining Fig. 16, the mind map Fig. 17, and all clusters, the most expressive cluster group formed was personality dimensions, making it easy to see how close the criteria are within the clusters and the responsiveness of the clustering algorithm. Also, "communication," the main concern from the SLR findings, repeat the result now at the cluster groups "Team Communication," was the most expressive in terms of clusters and criteria. However, it may look like the cluster "Team Organization and Attitude" does not fit this cluster group. Nevertheless, looking at the criteria inside this cluster, we noticed the criteria: contribution to team effort (C029), problem solving (C118), and capability to adopt team members (C202); thus, it is possible to detect the similarity of this actual cluster.

IV. CONCLUSION

Globalization spurred a new era of Global Software Development (GSD), followed by the gig economy (GE) phenomenon, which together caused significant transformations in software development markets, especially after the recently disrupted supply chain. Because of this scenario, many companies have started changing their business benchmarks. In this study, we aimed to identify what matters in hiring professionals for GSD to assist organizations looking for suppliers and partners.

This article identified the criteria for hiring professionals in the GSD or GE context and proposed a novel approach to clustering them. To do so, we collected the criteria from a broad subject through an SLR, then applied the SBERT algorithm to get the sentence embeddings. Further, with the sentence embedding obtained, we cluster the criteria by applying the *k*-means algorithm. After that, we innovatively and responsively grouped the clusters formed by repeating the SBERT and *k*-means algorithms and created its mind map. In summary, following the research questions (RQ), the accomplished goals were:

1) *RQ1:* We found a total of 65 documents.
2) *RQ2:* Appendix A displays the 319 criteria found and their definitions.
3) *RQ3:* Fig. 9 shows that "Communication" (51%) and "Trust Building" (43%) were the most cited criteria in the SLR database.
4) *RQ4:* SI-file[10] shows all criteria that stand for an indicator. Table IX shows the indicator correlations. Finally, Fig. 13 shows the cocitation network, in which the snowball search technique makes it possible to produce a responsive list of 319 criteria.
5) *RQ5:* Fig. 17 shows the mind map of the hierarchical structure of the cluster group formed by the criteria clusters.

[10][Online]. Available: https://bit.ly/SI-FILE-IEEE-TEM

Further, these outcomes have pedagogical implications since they can support specialists from education institutions in designing new domains (hard or soft skills) for their courses. Consequently, this work can be valuable to practitioners to assist in hiring professional processes in the GSD or GE context. In addition, the clustering algorithm SBERT for sentence embeddings and *k*-means for clustering demonstrated responsive results.

Boundaries even need to be overcome in future works. For example, further research should assess scientific databases besides the Web of Science and Scopus. Although the Boolean mix was high, we may have overlooked some papers or meaningful conference papers on GSD or Gig Economy. For future works, through the mind map done, make a 3-D graphic representation with a relative weight of the cluster groups. Furthermore, an exploratory investigation could employ SBERT to encode all criterion definition sentences of the sources retrieved through SLR and notice whether the manually identified criterion definitions are exhaustive or if it was missed any sentence close in meaning and context to a criterion definition in terms of cosine-similarity. Moreover, the next step of this study is to perform one empirical research with the practitioners to validate the criteria and create a relationship between cause and effect prioritization.

Conflicts of Interest: All authors have approved the manuscript and agree with its submission. Furthermore, we confirm that this manuscript has not been previously published and is not considered for publication in any other journal. Therefore, no conflict of interest needs to be disclosed.

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