FEDERAL UNIVERSITY OF ITAJUBÁ
POS-GRADUATION PROGRAM IN INDUSTRIAL ENGINEERING

What Matters in Hiring Professionals for Global Software Development or Gig Economy?

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As a partial requirement for Doctor of Science's title, this is the thesis submitted to the Pos-Graduate Program in Industrial Engineering of the Federal University of Itajubá.

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Thesis approved by the examination board in February 02^{th} of 2023, fulfilling part of the requirements to obtain the title of Doctor of Science in Industrial Engineering.

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I dedicate this fruit of nearly six years of hard work to my daughter and wife, who patiently gave me the strength and inspiration to get started and keep going.

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"No one can go back and make a renewed beginning.
However, we can start right now and make a new ending."
(Chico Xavier)

ABSTRACT

Supply chains are susceptible to uncertainties, such as large-scale natural disasters, manufacturing fires, terrorist attacks, widespread electrical shutdowns, financial and political tension, and wars. Therefore, rising unemployment rates have driven the workforce into short-term contracts or the on-demand market known as the gig economy. However, selecting skilled professionals is difficult and risky when organizations are immersed in fast-paced environments. In this context, we investigated the analysis scenario of contracting professionals in global software developments (GSD). This thesis aims to develop clusters of criteria for hiring self-employed professionals in the "*Global Software Development*" or "*Gig Economy*" context. We systematically reviewed 319 criteria in 65 papers and grouped them into two innovative ways. Thus, we obtained 25 criteria clusters and a hierarchical structure with their relationships, indicating that we had only 40% of the cause. We are proposing two innovative criteria grouping methods. The first delivers a fast aggregation clustering, and the second with the relationships between the criteria clusters. This tool can be handy for researchers in exploring new data via literature review or even through surveys. Another point is that the practitioners could easily use the spreadsheet with all the data, remove or join new criteria, and run the algorithm to create new clusters on their own. The main results were, firstly, for the applicants, in software development, the project requirements are gathered over the clients and stakeholders; this process involves rich and looping communication. Secondly, the enterprises first check the criteria clusters. Then, the list of criteria, and taking into account the job position or profile, they choose how to make the hiring process, reflecting on the relationship of criteria clusters (cause/effects). Finally, these results also imply the design of new subjects for computer science courses, mainly concerning soft skills, as highlighted in the Communication criteria cluster, in which we have a list of criteria highly cited in SLR.

Keywords: Criteria Selection, hiring, NLP, BERT, DEMATEL, MCDM, Cluster, 3D

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LIST OF ABBREVIATIONS AND ACRONYMS

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
AR	Autoregressive
BERT	Bidirectional Encoder Representations from Transformers
CBOW	Continuous Bag-of-Words
CLIR	Cross-Language Information Retrieval
CNPq	National Council for Scientific and Technological Development (in Portuguese: Conselho Nacional de Desenvolvimento Científico e Tecnológico)
DEA	Data Envelopment Analysis
DEMATEL	Decision-Making Trial and Evaluation Laboratory
DM	Data Mining
ELECTRE	ELimination and Choice Expressing Reality (in French: ELimination Et Choix Traduisant la REalité)
ELMo	Embeddings from Language Models
ESS	Sum of Square
FAHP	Fuzzy Analytical Hierarchy Process
FMADM	Fuzzy Multi-Attribute Decision-Making
FTS	Follow the Sun
GA	Genetic Algorithm
GE	Gig Economy
GRA	Gray Relational Analysis
GSD	Global Software Development
GPT	Generative Pre-Training

GWP	Gross World Product
KPI	Key Performance Indicator
KT	Knowledge transfer
HCA	Hierarchical Cluster Analysis
IFMM	Intuitionistic Fuzzy Muirhead Mean
IoT	Internet of Things
IR	Information Retrieval
IT	Information Technology
IRM	Influential Relation Map
LSTM	Long Short-Term Memory
MADA	Multi-Attribute Decision Analysis or Multi-Attribute Decision Aiding
MADM	Multi-Attribute Decision Making
MAUT	Multi-Attribute Utility Theory
MAVT	Multi-Attribute Value Theory
MCDA	Multi-Criteria Decision Analysis or Multi-Criteria Decision Aiding
MCDM	Multi-Criteria Decision Making
MLM	Masked Language Model
MMDE	Maximum Mean Deentropy
MODA	Multi-Objective Decision Analysis or Multi-Objective Decision Aiding
MODM	Multi-Objective Decision Making
MOGA	Multiple objective genetic algorithm
MOORA	Multi-Objective Optimization based on Ration Analysis
NLP	Natural Language Processing
NSP	Next Sentence Prediction
OpenAI GPT	Generative Pre-trained Transformer
OVV	Out-of-Vocabulary

PCA	Principal Component Analysis
PMBOK	Project Management Body of Knowledge
PPM	Project Portfolio Management
PPS	Project Portfolio Selection
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses
PROMETHEE	Preference Ranking Organization Method for Enrichment of Evaluations
RCM	Requirements Change Management
R&D	Research and Development
RNN	Recurrent Neural Networks
R&R	Repeatability and Reproducibility
SEM	Structural Equation Modeling
SPI	Software Process Improvement
SLR	Systematic Literature Review
TF-IDF	Term Frequency-Inverse Document Frequency
SMART	Simple Multi-Attribute Rating Technique
STS	Semantic Textual Similarity
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	Multi-criteria Optimization and Compromise Solution (in Serbian: VIseKriterijumska Optimizacija I Kompro-misno Resenj)
WoS	Web of Science Core Collection
WSS	Within-Clusters Sum of Squares

LIST OF SYMBOLS

c_{nnn}	Criteria collect in the SLR
P-value	Pearson correlation
$w_{i,j}$	Weight for term i in document j
N	Number of documents in the corpus
$tf_{i,j}$	Term frequency of term i in document j
df_i	Document frequency of term i in the corpus
$d_{A,B}$	Ward's distance between two clusters A and B
WSS	Within-Clusters Sum of Squares
k	Number of clusters
SSE	Euclidean distance
$cos(s_1, s_2)$	Cosine similarity between two sentences
h_T	Hidden state at time t
r	a context vector generated from the sequence of the hidden states
$p(Y)$	Joint probability into the ordered conditionals
s_i	RNN hidden state
α_i	Weight of each annotation h_T
$\hat{x}$	The same text sequence with masked tokens
$\bar{x}$	An array of masked tokens
$e(x)'$	represents the embedding of token x
H_θ	Transformer that transforms each token of text sequence into a hidden vector
L_{ce}	Distillation loss of DistilBERT
o	Classification Objective Function of Sentence-BERT
B_m	Individual direct-influence matrix
b_{ij}	importance of alternative i related to alternative j in the matrix B_m

E	The practitioners interviewed (decision group)
m	The number of practitioners
X	Normalized initial direct-relation matrix
T	Normalized group direct-influence matrix (in classic DEMATEL) or Normalized Pairwise comparison matrix for all criteria (in classic AHP)
R	Sum of columns in matrix T
D	Sum of rows in matrix T
$T^{'}$	Inner dependence matrix
φ	threshold value to draw the IRM in DEMATEL
g_n	Criteria clusters
G	Criteria clusters which correspond to each group of criteria $G = g_0, g_1, \ldots, g_n$
NG	NLP clusters groups of criteria clusters $NG = ng_1, ng_2, \ldots, ng_n$
ng_n	Clusters groups of the criteria clusters by NLP only

CONTENTS

1 INTRODUCTION

1.1 Context, relevance, and research contributions

Disruptions in supply chains have enormous financial impacts and in some cases, cause a permanent loss of market share (TOLOOIE *et al.*, 2020). Many countries imposed stringent *lockdown* measures to contain the pandemic and protect susceptible populations in 2020 (FERNANDES, 2020; WANG *et al.*, 2020), 2021 (SOUZA *et al.*, 2021a; BBC, 2021), and 2022 (WU *et al.*, 2022). Meanwhile, global economic activity contracted dramatically and led to considerable uncertainties in demands, and massive disruptions in global and domestic supply chains (MAHAJAN; TOMAR, 2021; IMF, 2020; WU *et al.*, 2022). The World Economic Outlook shows that the lockdowns and social distancing imposed by COVID-19 have a considerable negative effect on economic activity (IMF, 2020), where the gross world product (GWP) decreased by 3.267% in 2020. Nevertheless, supply chains are also susceptible to other uncertainties, such as large-scale natural disasters, manufacturing fires, terrorist attacks, widespread electrical shutdowns, financial and political tension (GOVINDAN *et al.*, 2017; TOLOOIE *et al.*, 2020), and wars (BARNES *et al.*, 2022).

In business, face-to-face and personal interactions are crucial, especially when making sensible decisions or transferring essential skills and know-how. For some companies, the recent worldwide disruptions made it possible to test some technological solutions. Afterward, the stock prices of these companies skyrocketed in the immediate aftermath of the crisis. Thus, the post-COVID-19 world may probably see a rise in global virtual teams organized around different technological solutions, including eventually augmented and virtual realities (MAHAJAN; TOMAR, 2021). However, the migration to virtual environments may still find room, especially in developing countries. For instance, global online retail sales are less than 30% of the total retail sales in those countries. Consequently, retail sales in physical stores are higher, more than 70% of total retail sales in 2020 (LIU; RABINOWITZ, 2021). Thus, in a pandemic context, online shopping still has a long way to advance, contrary in developed countries.

In this online environment, some new applications arise, like paperless banking, to reduce contact, like document (paper) approvement. Paperless banking means functions performed without paperwork, like online banking, mobile banking, and digital banking, making the essential demands for economic and social life transactions possible (MALUSARE, 2020; IMF, 2020).

The adoption of new information and communication technologies and the proliferation of mobile technologies caused a revolution in the negotiability of outsourcing services.

Subsequently, it was soon possible to create a temporary and on-demand job market, allowing companies, through digital platforms, to reduce costs and access qualified and specialized labor. This market is known as Gig Economy (GE) (CHURCHILL; CRAIG, 2019; LEHDONVIRTA *et al.*, 2019).

The fourth industrial revolution created a new form of the industrial revolution through the intellectualization of systems based on big data and artificial intelligence (PARK; HUH, 2018), which is increasingly demanding projects and software development. At GE, the primary buyer countries categorize the services announced on digital platforms as software development and technology (KÄSSI; LEHDONVIRTA, 2018). In GE's context, job vacancies and project positions are relatively common in sectors that employ well-paid IT consultants and technicians trained in elite schools, including financial services and professional and business services (FRIEDMAN, 2014). The categories of software development and technology services include data science, game development, mobile development, question and answer (Q&A), server maintenance, software development, Web development, and Web scraping (KÄSSI; LEHDONVIRTA, 2018; WOOD *et al.*, 2019).

By 2025, there is a prediction to be 42 billion IoT-connected devices globally, state the World Economic Forum (2021). It is not just an internet of things. It is becoming an internet of everything: smart industries, logistics, homes, cities, and healthcare. One of the main concerns around the IoT is technological fragmentation and the industrial internet of things that still under development (PARK, 2019; KHANDELWAL *et al.*, 2019). Organizations in all sectors, with this technology, recognize that they continue to evolve into data technology companies and that their business models are being partially or transformed by software (MUNTÉS-MULERO *et al.*, 2019).

In the fourth industrial revolution, there is a new paradigm between customer and supplier, in which machines and products share a sort of intellect and history in a network. Mass production also gives rise to small batch production, demanding fast, flexible, and personalized delivery capabilities (PARK; HUH, 2018). As a result, a high level of product complexity, more individualized products, reduced development time to delivery, and a form of interconnected and globalized cooperation are present trends in product development processes (KIND *et al.*, 2019).

Changes in business models, technology, and the global integration of economies significantly impact the ways of working (RYDER, 2019; KIM; SUH, 2021). The nature of qualified work requires considerable flexibility and opening possibilities for self-employed workers (HODGSON, 2016). These jobs are performed by short-term and flexible contracts, without employment, based on a digital platform, working for a defined time or only to complete a specific task (FRIEDMAN, 2014; ROSENBLAT; STARK, 2016). Employees point out some hiring problems in this type of work, such as the lack of access, autonomy, transparency, communication and accountability, discipline, classification, work allocation, and, in some cases, high costs (ROSENBLAT; STARK, 2016; WOOD *et al.*, 2019; WRIGHT *et al.*, 2018; DENG; GALLIERS, 2016).

Surviving in this modern and global business environment demands overcoming different agile supplier selection process issues. Additionally, the structured selection of supply partners can increase the effectiveness, efficiency, quality, safety, and profit of companies (KUMAR *et al.*, 2019). When done correctly, the selection of suppliers reduces the company's operating costs and improves its operational quality (SAMUT; ERDOGAN, 2019). Supplier assessment is a multi-criteria decision-making problem whose criteria instantiate different business perspectives. Thus, selecting the proper criteria is a critical prior step to selecting the most suitable suppliers (ZEYDAN *et al.*, 2011).

Global Software Development (GSD) is a recent software development approach that has become a demand for the software development industry to generate several economic, quality, and financial benefits (SHAMEEM *et al.*, 2020; KHAN *et al.*, 2019). As a result, GSD has been an emerging trend in software development globally. This scenario boosts the suppliers and consumers in diverse geographic areas with diverse cultures and time zones and spreads the development team across multiple locations, and countries (RAHMAN *et al.*, 2021). Nevertheless, the software distribution dimensions like geographical, cultural, and temporal distances make these activities more complex with several challenges (AMMAD *et al.*, 2019; KHAN; AKBAR, 2020).

Nonetheless, we look at the worldwide contemporized software development environment to show this study's relevance. The technological evolution pushes enterprises to concentrate solely on acquiring relevant skill sets to compete at global benchmarks. In October 2022, a Deloitte survey of 116 CEOs pointed out that a shortage of qualified labor was the most significant external issue encountering their companies, and 71% believe the widespread talent deficiency will persist (DELOITTE, 2022). Recently, Brazil experienced these challenges, as it lacked some essential skills for the demands of developing new processes (CEZARINO *et al.*, 2019; SINGH *et al.*, 2021). The shortage of professional technology forced companies to launch a new way of selecting and hiring professionals, and recently a renowned IT company (XP Inc.) created its graduation course in Brazil (INFOMONEY, 2022).

Many researchers investigated Global Software Development (GSD), examining the literature and related works. 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 (KHAN; AKBAR, 2020; KAMAL *et al.*, 2020; AKBAR *et al.*, 2020b). Some researchers are dedicated to analyzing the GSD knowledge transfer (NIDHRA *et al.*, 2013; HUMAYUN; CUI, 2013; VIZCAÍNO *et al.*, 2018), in finding out the GSD challenges (YASEEN *et al.*, 2016; ILYAS; KHAN, 2017; VIZCAÍNO *et al.*, 2019), the communication context (AMMAD *et al.*, 2019; KHAN *et al.*, 2019), problems (KOMMEREN; PARVIAINEN, 2007; HUSSAIN *et al.*, 2021; SHAMEEM *et al.*, 2020), risks (LAMERSDORF *et al.*, 2012;

SUNDARARAJAN *et al.*, 2019), success factors (ILYAS; KHAN, 2016; GULZAR *et al.*, 2018; AKBAR *et al.*, 2020), and a model proposal (ILYAS; KHAN, 2012; SANGAIAH *et al.*, 2015b; GOPAL *et al.*, 2018). Other researchers dedicated to analyzing the sharing economy environment (KIM; SUH, 2021; CURTIS *et al.*, 2020) and others analyzed only the contract side (FLINCHBAUGH *et al.*, 2020).

Also, we can find many systematic literature reviews (SLR) on GSD, team performance (NGUYEN-DUC *et al.*, 2015), follow the sun (KROLL *et al.*, 2018), team communication (DEFRANCO; LAPLANTE, 2017), communication in Gig Economy (GE) (LUDWIG *et al.*, 2022), process improvement (KUHRMANN *et al.*, 2016), software integration (ILYAS; KHAN, 2012; ILYAS; KHAN, 2016), software quality (SHANYOUR; QUSEF, 2019), and requirements implementation (YASEEN *et al.*, 2016). Goyal & Gupta (2020) (GOYAL; GUPTA, 2020) analyzed the team selection, but they did not demonstrate how they collected the criteria.

Even so, we did not find a paper that examined the contract's criteria in an open GSD subject. In addition, the criteria definition could have been more efficient in several studies (HASSAN *et al.*, 2019; IQBAL *et al.*, 2022; GULZAR *et al.*, 2018), compromising the research results and even for comparisons. For this reason, the criteria prioritization results in the studies investigated usually reached different results.

Fig. 1.1 emphasizes the research delimitations, starting from a broad subject, the fourth industrial revolution, and going inside the disruptions in supply chain management, global software development (GSD), the Gig Economy (GE), and, finally, what matters in hiring professionals.

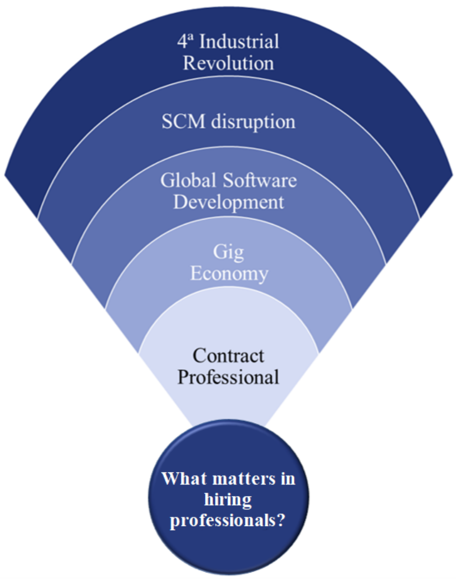


Figure 1.1 – Research delimitations - What matters in hiring professionals?

Source: author.

Therefore, this thesis research question is linked to an essential topic in the current social and economic situation: what matters in hiring professionals for software development in a long-distance and fast-changing environment?

This thesis 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 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. The main contributions of this thesis are summarized as follows:

- The criteria and clusters of criteria presented in this work can be valuable to practitioners to assist them in hiring professionals in the GSD or GE context.
- Additionally, these results have pedagogical implications since they can help specialists from education institutions design new disciplines (hard or soft skills) for their courses.
- We introduce a novel application of Natural Language Processing (NLP) for dimensionality reduction by criteria aggregation instead of multi-criteria decision-making (MCDM) or by experience from researchers or practitioners in the GSD context.
- 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 and quickly.
- We propose an integrated NLP-DEMATEL - natural language processing (NLP) and multi-criteria decision-making (MCDM) - a 3D systematic approach to cluster and make a hierarchical structure of criteria cluster.

In this research, we hold three innovations. First, from a broad subject, we produce a criteria cluster hierarchical structure for hiring professionals in the GSD/GE context. Then, in the second step of the methodology, we create 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. Finally, with the insight of three practitioners, we propose a method to integrate the NLP/DEMATEL approach and to create a hierarchical structure of criteria clusters with the relationship between the clusters and a 3D graph of the hierarchical structure relationships. To accomplish this goal, the extended research questions (RQ) of this study are as follows:

- RQ1: Is there any article regarding some selection criteria in the "gig economy" or GSD?
- RQ2: What are the issues, gaps, challenges, barriers, best practices, success factors, risks, and threats for contracting professionals in the "gig economy" or GSD?

- RQ3: What are the most criteria cited in literature when contracting suppliers or software developers or hiring professionals in the "gig economy" or GSD?
- RQ4: Can the criteria represent an indicator? What findings can we produce by investigating the SLR results, like co-citation network and indicators correlations?
- RQ5: Can we cluster the indicators innovatively and responsively?
- RQ6: What are the relationships between the criteria clusters?

Following, we present this work's propositions, objectives, and research delimitations.

1.2 Investigated Propositions and Objectives

The literature discerns that the hypothesis is verified by quantitative metrics and indicators, while qualitative indicators verify a proposition. Accordingly, this thesis propositions are 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?

1.2.1 General objectives

Based on the previous discussion, the general objective of this work is to develop clusters of criteria for hiring self-employed professionals in the "*Global Software Development*" or "*Gig Economy*" context.

1.2.2 Intermediate objectives

To achieve the general objective, we observed the following intermediate and complementary objectives.

- Identify and record the attributes (issues, gaps, challenges, barriers, best practices, success factors, risks, and threats) related to the context of the GSD/GE in two central databases, Scopus® and Web of Science Core Collection®, through a systematic literature review (SLR). We choose these databases as they stay the primary sources of citation data.
- Transform the attributes found in the literature in criteria, convert them into indicators, and report SLR results.
- Cluster, the criteria list, using NLP/SBERT/*k*means algorithm in a Python framework. The choice of the Python language was due to its outstanding versatility for developing different types of applications.
- Create a fast and initial hierarchical structure by clustering the criteria clusters formed employing only the same algorithm (NLP/SBERT/*k*means).

- Obtain the direct influence of DEMATEL MCDM throw three interviews with practitioners.
- Apply the DEMATEL MCDM to get the Influential Relation Map (IRM).
- Create the third axis by employing the NLP/SBERT/Pytorch algorithm and obtain a quantitative semantic textual similarity (STS).
- Finally, propose a new hierarchical structure in a 3D graph by integrating the Natural Language Processing (NLP), the *k*means iterative partitional algorithm, the Multi-Criteria Decision-Making (MCDM) DEMATEL, and Ward linkage hierarchical algorithm into a novel approach of hierarchical structure.

1.3 Methodology strategy

The research apprised by this Thesis may observe many classifications. Concerning its nature, it is an **applied** research showing practical interest in solving real-world problems (APPOLINÁRIO, 2006). Concerning its objectives, it is a **normative** research aiming to improve techniques and approaches already available in the literature (BERTRAND; FRANSOO, 2002). Finally, concerning the problem approach, it is classified as **quantitative** since it decrypts most results into numbers (GERHARDT; SILVEIRA, 2009).

The research methodology used in this article was **modeling**, specifically, the model proposed by Bertrand e Fransoo (2002). For these authors, modeling and simulation research can be divided into axiomatic and empirical. Axiomatic research processes knowledge about a variable based on already standard models in the literature. On the other hand, empirical research uses field data and seeks to develop models to solve a specific problem.

1.4 Research Delimitation's

The following characteristics delimited the outcomes of this thesis:

(i) Research Area: the scope of this work is limited to the GSD or GE context. It stands for GE context, other words used in the boolean combination to refer to a short-term contracted professional. The proposed 3D hierarchical criteria groups may be suitable for other fields of study within or outside the GSD. In addition, the proposed methodology may be appropriate for other research topics involving SLR.

(ii) Research databases: 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. However, we can minimize this delimitation by analyzing the co-citation network (See Subsection 2.1.2.5).

(iii) Research keywords: the keywords used to find articles and studies may not be enough to return all possible viable results. Nevertheless, we reviewed the search string with a renowned IT company's head and one external specialized science computer teacher. Also, seeking to complete an entire list of criteria, we make a snowball search from the co-citation network.

(iv) The thesis 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.

(v) The attributes comprising issues, gaps, challenges, barriers, best practices, success factors, risks, and threats are collected in a broad subject of any criteria involved in the outsourcing or offshore context. We do not intend to show this classification separately as other papers did.

(vi) The proposed criteria selection approach integrates the well-known MADM method DEMATEL and a novel approach, NLP/BERT. However, we do not use a fuzzy approach. Moreover, we use a more straightforward pre-trained BERT database for initial clustering converting the attributes into criteria groups. In some cases, researchers are challenged with two points: in the concise text of the criteria definition and in creating the group's definition of criteria.

(vii) A disadvantage to being overcome: in the phase of the interviews with practitioners, we have extensive data input to be made by the experts; hence, we prepare and test a more understandable spreadsheet with one practitioner before the three interviews.

1.5 Structure of the Thesis

We have structured this thesis into five chapters. The second presents the Scientific Foundations. The third chapter presents the proposal for a combined approach of NLP and DEMATEL to form the 3D hierarchical grouping for hiring professionals in GSD/GE. Then, the fourth chapter presents the construction of the proposed clustered list of criteria process. Finally, the fifth chapter presents conclusions. Beneath, we briefly remark on each chapter's content:

- **Chapter 2**: First, we present the SLR and its findings. The SLR especially finds all the attributes and criteria employed to contract in GSD/GE. Then, we present the used NLP approach and algorithms. Lastly, we introduce the DEMATEL MCDM method.
- **Chapter 3**: This chapter presents how we construct the proposed method for a 3D hierarchical clustering of the criteria group.

- **Chapter 4**: Demonstrates in detail the results and graphical elements of the NLP/DEMATEL 3D hierarchical structure of criteria cluster.
- **Chapter 5**: Finally, in this chapter, we present the conclusions and the recommendations for further research on the subject.

2 SCIENTIFIC FOUNDATIONS

This chapter presents the scientific foundations necessary to carry out this thesis. First, we present a systematic literature review (SLR) of publications of criteria for hiring self-employed professionals in the GSD or GE context. This Section's main contributions are providing a detailed report on the subject and finding research opportunities that this thesis and future research can investigate.

Later, we introduced Natural Language Processing (NLP) (Section 2.2), followed by a subsection briefly introducing word embedding (Subsection 2.2.2), TF-IDF (Subsection 2.2.3), transformers (Subsection 2.2.5), BERT (Subsection 2.2.6), SBERT (Subsection 2.2.8), and clustering algorithms (Subsection 2.2.4). Finally, we present the context of DEMATEL MCDM approaches (Section 2.3).

2.1 SLR methodology and findings

This section, a systematic literature review (SLR), provides a complete overview of the criteria for hiring self-employed workers for software development. We aim to figure out in the literature the criteria to be observed to make a limited contract in global software development, especially when there are uncertainties in demand and disruptions in global supply chains. This systematic literature review was necessary to have a comprehensive and complete list of criteria concerning the hiring process under a short-term contract (GE) in GSD. To fulfill this objective, we followed the research questions RQ1, RQ2, RQ3, and RQ4.

We divide this section into two parts, starting with the SLR methodology and conceptual frameworks and then showing the SLR findings. Fortunately, the findings of our analysis will be beneficial to the academic community and the decision-makers.

2.1.1 SLR methodology

The research methodology follows the recommendations of Durach et al. (DURACH *et al.*, 2017), Kitchenham and Charters (KITCHENHAM *et al.*, 2002), and the PRISMA framework (MOHER *et al.*, 2009) (Preferred Reporting Items for Systematic Reviews and Meta-analyses). In addition, the PRISMA statement plans to aid authors in enhancing the reporting of systematic literature reviews through a 27-item checklist (MOHER *et al.*, 2009). We show these checklists and the framework in Appendix PRISMA CHECKLISTS by Tables A.1, A.2, and A.3, and the Fig. A.1.

We built the research protocol shown in Fig. 2.1 - The systematic literature review protocol to clarify all the steps performed. Then, we divided the research protocol into three sections. In Chapter 1, we have already presented the motivation for the literature review and research questions. In this Subsection 2.1.1 - SLR methodology, we explain the process of defining the search string, the research strategy, the preview database, standardizing and validating the data, and finally, the studies screening. Finally, Subsection 2.1.2 - SLR findings presents the data extraction, processing, systematic literature review, and findings.

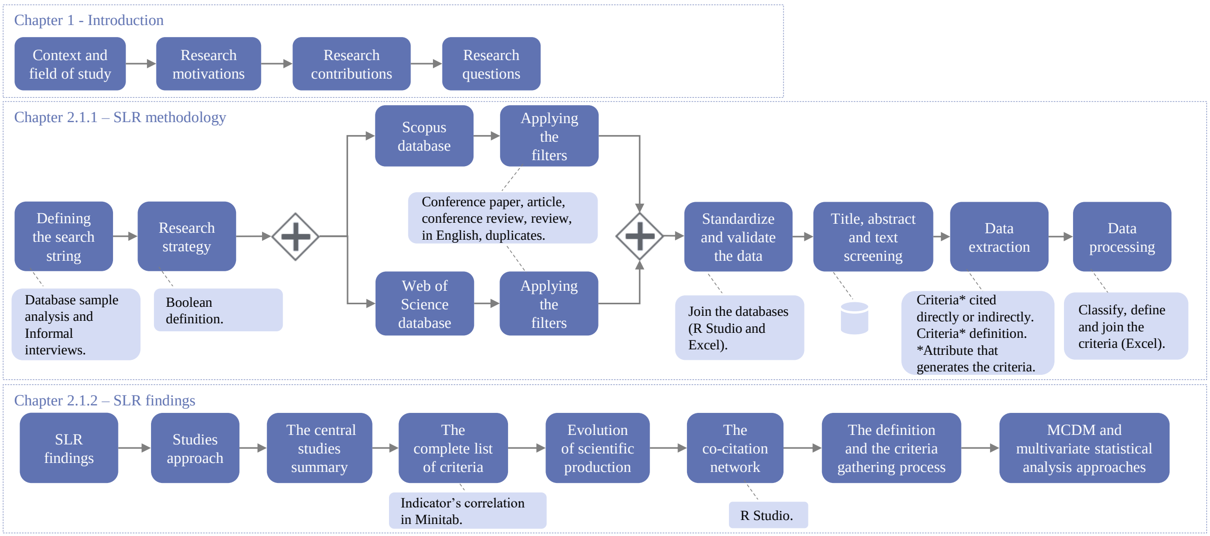


Figure 2.1 – The systematic literature review protocol

Source: author.

Before retrieving a potentially relevant literature sample, the next step was to build a search string. This construction occurred 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 the terms 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 these keywords, looking for the Boolean combinations and the database more closely to papers related to supplier selection criteria, we use the keywords "selection", "evaluation", "analyze", and "analyse". We choose this open combination to get the broad contract suppliers' data. Furthermore, we choose two control articles (KAMAL *et al.*, 2020), (GOYAL; GUPTA, 2020) to validate the boolean combination for a precise and correct process definition. Finally, Table 2.1 - Strings used to perform the search shows the searching keywords used in this work.

We performed this search in the two central widespread databases available Scopus® and Web of Science®. These databases remain the primary sources for citation data, where the interdisciplinary coverage of these databases represents a significant strength for the study and comparison of different scientific fields(MONGEON; PAUL-HUS, 2016). However, more articles can be found outside those databases; this review's scope stays to only papers available

Table 2.1 – Strings used to perform the search

Boolean combination
"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

Source: author.

in those two. The search started on July 29th, 2020, and the last update finished on September 9th, 2022. We found 3,052 results from 1972 (when the first article is dated) to 2022.

In the next step, we make 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. Regarding the language, we excluded articles that were not in English, excluding the duplicated articles among the query results and the duplicated articles between the two databases. At this point, we obtained 1,876 articles. Fig. 2.2 - SLR searching and selecting process as follows, and Fig. A.1 - PRISMA 2020 flow diagram for new SLR which included searches of databases and registers only in Appendix A, display an entire overview of the SLR searching and selecting process.

Figure 2.2 – SLR searching and selecting process

Source: author.

As shown in Fig.1.1, the research theme delimitation, we are in a marginal region of various themes, which is an emergent and new theme. Due to this, we also choose proceedings from prestigious international conferences; for example, some crucial documents such as BERT (DEVLIN *et al.*, 2018) and Hard and Soft Skills for a scrum (HIDAYATI *et al.*, 2020) would be out of SLR. To assess the sources and the database quality, we ranked the related sources based on their classification collected directly from Scopus®, based on their four quartiles.

Then, to determine the characteristics of the subjects or elements in the study and direct answers to research questions, we performed three screening steps, as shown in Table 2.2 - Inclusion and exclusion criteria of studies. Firstly, the titles were analyzed, and we rejected articles that did not suit the scope of this work. Afterward, articles were rejected based on their abstracts and, after that, on the full text. Each stage also evaluates the inclusion and exclusion criteria of the previous steps. Moreover, the author and co-advisor independently reviewed all the studies for pattern, then arrived at a final database consensus.

Table 2.2 – 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 excluded secondary studies similar to the scope of this study.

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

Source: author.

To assemble this process more effectively, we exported the two databases Scopus® and Web of Science® in Excel files. We assessed the selected literature in each file considering the study research questions and the inclusion and exclusion criteria, shown in Table 2.2. Since this is a broad subject, we first checked just the title, as we have many documents related to subjects other than software development.

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 Table 2.3 - Articles included in the literature review - 1/2 and Table 2.4 - Articles included in the literature review - 2/2. These Tables show, in sequence, the Authors and year of publications in crescent order, the title of the document, and in the last column, the number of attributes found in SLR.

Furthermore, as a sample of the selection process, although the studies of Bartneck et al. (BARTNECK *et al.*, 2015) and Mitlacher (MITLACHER, 2006) might appear to match the inclusion criteria, we excluded them because they did not focus on the criteria of the GSD's contract in a specific way.

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 software (RStudio Team, 2021), then we exported the final SLR database to an Excel spreadsheet, as shown in the support information file SI-file[1]. Likewise, SI-file shows the two main spreadsheets used in SLR: the principal information and criteria definitions. Where the first spreadsheet holds the principal data information of the studies in the SLR, the second holds the secondary details as the criteria definitions. We also use the secondary spreadsheet to create the criteria indicator groups, aiming to calculate their correlation.

We thoroughly read all documents in the database and classified and analyzed them according to the research protocol. In these 65 Documents, we extracted the criteria through spreadsheet support and independent collection; after that, the authors revised and validated the theoretical list of criteria.

After the accomplishment of the SLR, we collected 319 criteria. As shown in SI-file, in the *Criteria definitions* spreadsheet, we have in sequence: code, collected attributes, criteria, the criteria types (specific, measurable, achievable, relevant), then we have the criteria definition column, and following each column stand for each reference obtained from the SLR. Then, when we had a criterion definition for each reference, we put the original definition obtained from the study/reference inside the cell. After finishing this step, we join all the definitions obtained inside the "Criteria definition" column. The pseudocode 1 - Pseudocode of criteria definition method summarizes these steps, where the c_{nnn} is the total number of criteria collected in the SLR.

In addition, for the data extraction and processing sequence from the SLR database, we worked in two spreadsheets in the same Excel file: the principal information and criteria definitions. The principal information spreadsheet contains all the documents per line obtained from Scopus and Web of Science. Then, following the same process applied in the inclusion and exclusion criteria of studies, we created new columns for any point to be investigated.

Thereby aiming to verify if the attribute (criteria collected) cited in the study was defined or explained, we created one new column using the Likert scale: 1 = yes; 0.5 = partial; and 0 = no. As detailed in the following subsection, we also did a similar process for the studies approach, creating new columns to extract each data and the attribute (criteria collected) linking with each study.

[1] http://bit.ly/3FU3zlo

Table 2.3 – Articles included in the literature review - 1/2

Author	Title of the document and the number of attributes found	#
Kommeren e Parviainen (2007)	Philips experiences in global distributed software development	17
Chatzipetrou *et al.* (2011)	Software product quality in global software development: Finding groups with aligned goals	14
Dumitriu *et al.* (2011)	Issues and strategy for agile global software development adoption	19
Palacio *et al.* (2011)	Tool to facilitate appropriate interaction in global software development	3
Monasor *et al.* (2012)	Providing training in GSD by using a virtual environment	26
Ilyas e Khan (2012)	Software Integration Model for Global Software Development	19
Lamersdorf *et al.* (2012)	A rule-based model for customized risk identification and evaluation of task assignment alternatives in distributed software development projects	26
Richardson *et al.* (2012)	A process framework for global software engineering teams	25
Baldwin e Damian (2013)	Tool usage within a globally distributed software development course and implications for teaching	3
Humayun e Cui (2013)	An empirical study of the complex relationship between KMR and trust in GSD	1
Nidhra *et al.* (2013)	Knowledge transfer challenges and mitigation strategies in global software development—A systematic literature review and industrial validation	18
Avritzer *et al.* (2014)	Survivability models for global software engineering	5
Sangaiah *et al.* (2015a)	A fuzzy DEMATEL approach based on intuitionistic fuzzy information for evaluating knowledge transfer effectiveness in GSD projects	10
Sangaiah *et al.* (2015b)	A combined fuzzy DEMATEL and fuzzy TOPSIS approach for evaluating GSD project outcome factors	18
Nguyen-Duc *et al.* (2015)	The impact of global dispersion on coordination, team performance and software quality-A systematic literature review	7
Šablis e Šmite (2016)	Agile teams in large-scale distributed context-isolated or connected?	1
Bhatti e Ahsan (2016)	Global software development: an exploratory study of challenges of globalization, HRM practices and process improvement	28
Yaseen *et al.* (2016)	Critical challenges for requirement implementation in context of global software development: A systematic literature review	30
Ilyas e Khan (2016)	An exploratory study of success factors in software integration for global software development vendors	15
Kuhrmann *et al.* (2016)	How does software process improvement address global software engineering?	8
Defranco e Laplante (2017)	Review and analysis of software development team communication research	18
Imtiaz e Ikram (2017)	Dynamics of task allocation in global software development	13
Ilyas e Khan (2017)	Software integration in global software development: Challenges for GSD vendors	14
Vizcaíno *et al.* (2018)	A social network to increase collaboration and coordination in distributed teams	6
Gopal *et al.* (2018)	Integration of fuzzy DEMATEL and FMCDM approach for evaluating knowledge transfer effectiveness with reference to GSD project outcome	25
Gulzar *et al.* (2018)	A practical approach for evaluating and prioritizing situational factors in global software project development	40
Kroll *et al.* (2018)	Empirical evidence in follow the Sun software development: A systematic mapping study	3
Khan *et al.* (2019)	An Evaluation Framework for Communication and Coordination Processes in Offshore Software Development Outsourcing Relationship: Using Fuzzy Methods	7
Vizcaíno *et al.* (2019)	Evaluating GSD-aware: A serious game for discovering global software development challenges	12
Ammad *et al.* (2019)	An Empirical Study to Investigate the Impact of Communication Issues in GSD in Pakistan's IT Industry	44
Sievi-Korte *et al.* (2019)	Software architecture design in global software development: An empirical study	23
Sundararajan *et al.* (2019)	Variation of risk profile across software life cycle in IS outsourcing	10
Khan *et al.* (2019)	Fuzzy AHP based prioritization and taxonomy of software process improvement success factors in global software development	23
Shanyour e Qusef (2019)	Global Software Development and its Impact on Software Quality	14
Hassan *et al.* (2019)	A Policy Recommendations Framework to Resolve Global Software Development Issues	19
Sridhar e Vadivelu (2022)	Satellite phone development through an off-shore, outsourcing partnership: Client and vendor experiences	3

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

Source: author.

We worked with the criteria definitions spreadsheet parallel to the principal information spreadsheet. We designed this spreadsheet with the following columns: code, collected attribute, criterion, criterion definition, and new columns for each study in the SLR database. The column "code" begins with a sequential number of $c_1, c_2, \ldots, c_n$; where $n = 0, 1, \ldots, 9$, and c_{nnn} will

Table 2.4 – Articles included in the literature review - 2/2

Author	**Title of the document and the number of attributes found**	**#**
Lai *et al.* (2020)	Towards successful agile development process in software outsourcing environment: A systematic literature review	32
Alsanoosy *et al.* (2020)	Identification of cultural influences on requirements engineering activities	13
Akbar *et al.* (2020)	Multicriteria Decision Making Taxonomy of Cloud-Based Global Software Development Motivators	30
Moayedikia *et al.* (2020)	Optimizing microtask assignment on crowdsourcing platforms using Markov chain Monte Carlo	2
Shameem *et al.* (2020)	Taxonomical classification of barriers for scaling agile methods in global software development environment using fuzzy analytic hierarchy process	21
Akbar *et al.* (2020a)	A multivocal study to improve the implementation of global requirements change management process: A client-vendor prospective	21
Khan e Akbar (2020)	Systematic literature review and empirical investigation of motivators for requirements change management process in global software development	25
Akbar *et al.* (2020b)	A fuzzy analytical hierarchy process to prioritize the success factors of requirement change management in global software development	23
Goyal e Gupta (2020)	Intuitionistic fuzzy decision making towards efficient team selection in global software development	18
Hidayati *et al.* (2020)	Hard and soft skills for scrum global software development teams	29
Kamal *et al.* (2020)	Toward successful agile requirements change management process in global software development: A client-vendor analysis	23
Rafi *et al.* (2020b)	Multicriteria Based Decision Making of DevOps Data Quality Assessment Challenges Using Fuzzy TOPSIS	3
Kluge *et al.* (2020b)	Transformation action cycle: Suggestions for employee centered transformation to digital work in smes	7
Ali e Lai (2021)	Global Software Development: A Review of its Practices	33
Björkdahl e Kronblad (2021)	Getting on track for digital work: Digital transformation in an administrative court before and during COVID-19	5
Bastidas *et al.* (2021)	A Systematic Literature Mapping: risk-based testing in software development	12
Garro-Abarca *et al.* (2021)	Virtual Teams in Times of Pandemic: Factors That Influence Performance	7
Zhang *et al.* (2021)	Utilizing Virtual Crowd for Global Software Development	10
Rashid *et al.* (2021)	Green-Agile Maturity Model: An Evaluation Framework for Global Software Development Vendors	23
Rahman *et al.* (2021)	Empirical Investigation of Influencing Factors Regarding Offshore Outsourcing Decision of Application Maintenance	15
Nurrahman *et al.* (2021)	Prioritizing the software development methodologies in online gig economy project using analytic hierarchy process	8
Subbarao e Mahrin (2021)	Data Consolidation in Global Software Development Projects: A Grounded Theory	11
Hussain *et al.* (2021)	Prioritizing the Issues extracted for Getting Right People on Right Project in Software Project Management from Vendors' Perspective	14
Khan e Akbar (2022)	Software development process evolution and paradigm shift - a case study of Malaysian companies	9
Castro-Hernandez *et al.* (2022)	Effect of Temporal Patterns on Task Cohesion in Global Software Development Teams	3
Rafi *et al.* (2022)	Decision-Making Taxonomy of DevOps Success Factors Using Preference Ranking Organization Method of Enrichment Evaluation	16
Iqbal *et al.* (2022)	Model to Cope with Requirements Engineering Issues for Software Development Outsourcing	42
Ludwig *et al.* (2022)	Communication in the Gig Economy: Buying and Selling in Online Freelance Marketplaces	4
Trinkenreich *et al.* (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.

Source: author.

be the last one criterion. Next, column “collected attributes” is extracted from the studies. Then, column “criteria” display the final criterion established through the conversion process of raw data extracted by the researchers. Subsequently, in column “criteria definition”, we address each criterion description. Finally, with a partial or complete description of the collected attribute, we created a sequence of columns by each study linked with their code.

We extracted the required and needful data with these two spreadsheets to provide the

Algorithm 1 - Pseudocode of criteria definition method

Input: The attributes present in the 65 documents of the SLR database.
Output: The criteria and its definition.
for $Documents = 1, 2, \ldots, 65$ **do**
  for $Attributes = 1, 2, \ldots, N$ **do**
    Collect the $Attributes$ for any $Documents$
    Place in their respective $Code$ row
    Plane in their respective $Documents$ column.
  end for
end for
for $Criteria = c_{001}, c_{002}, \ldots, c_{nnn}$ **do**
  for each $Documents$ column and $Code$ row **do**
    Join the $Criteria$ c_{nnn} definitions in the "criteria definition" column.
  end for
end for

Source: author.

SLR findings in the following subsections. SI-file shows these two spreadsheets: the principal information and criteria definitions. Where the first spreadsheet contains the principal data information of the papers in the SLR, the second spreadsheet contains the secondary information with the criteria definitions and their group. To do that, we need to arrange the definitions of the criteria. First, we only join all attribute definitions inside the respective criteria. Then, we organize them succinctly and understandably based strictly on the SLR database. But, in many cases, there are no definitions, so we search in Google Scholar® to get the most recent definition for the criteria. Finally, every criterion was cited.

We define the group of the criteria as an indicator following the SMART KPI's (SHAHIN; MAHBOD, 2007; PODGóRSKI, 2015). Table 2.5 - Grouping the criteria as a SMART indicator encounters the leading indicator criteria group: Specific - IGS, Measurable - IGM, Achievable - IGA, and Relevant - IGR. Then, in the following line, we can find the questions used to classify each criterion. Finally, the criteria were classified as direct and indirect, objective and subjective, qualitative, quantitative and quali-quanti, inside, outside and both, respectively, 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® (HELSEL, 2011). So, we applied the Pearson correlation coefficient, a linear correlation coefficient for measuring the relationship, or association, of two variables (DENG *et al.*, 2021).

Afterward, with the criteria groups definition, we explained each type of group, as shown in Table 2.6 - Table Definition of the SMART indicator group types.

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

Table 2.5 – Grouping the criteria as a SMART 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

Source: Adapted from Shahin e Mahbod (2007), Podgórski (2015).

Table 2.6 – Definition of the SMART 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.

Source: author.

and studies may not be enough to return all possible viable results, and 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 co-citation network through the bibliometrix package (ARIA; CUCCURULLO, 2017) in R and RStudio software (RStudio Team, 2021) to build the co-citation figure, aiming to meet an entire list of criteria with snowball searches by the co-citation network (WOHLIN *et al.*, 2022; WOHLIN *et al.*, 2020) Moreover, using the same package, we also analyzed the evolution of scientific production.

The following Subsection 2.1.2 presents the results and discussion of the SLR.

2.1.2 SLR findings

This subsection 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 co-citation network, the definition, and the criteria gathering process, and multicriteria decision-making approaches.

2.1.2.1 The studies approach

The approach of the studies and the authors are shown in Appendix B by the Tables B.1, B.2, and B.3. We based and adapted the approach by Ferreira de Araújo Lima *et al.* (2020) 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:

- Survey/interview, when the researchers used a questionnaire or made one or more interviews;
- Literature review, when the researchers made a simple literature mapping or an SLR to find the criteria;
- Conceptual model proposal, when the researchers proposed a tool;
- Single case study when they focused on only one stakeholder;
- Multi-case/ long case study when they focused on two or more stakeholders;
- 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 selected primary studies consist of 62% of survey/interview, 51% of literature review, 29% of a conceptual model proposal, 18% of single case study, 14% of multi-case/ long case study, and 9% of the model proposal and test, as shown in Table B.1.

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:

- Context analysis when the researchers investigated the criteria in a general perspective;
- Identification when the researchers are looking for new criteria;
- Evaluation when the criteria pass throw for some data analysis;
- Treatment when the criteria pass by a more robust process methodology;
- 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% of identification, 34% of treatment, 29% monitor and report, and 29% of context analysis, as shown in Table B.2.

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

- Problems/ issues/ gaps when we recognized that it was a fact occurred;
- Challenges/ barriers when the scenario was not a fact, or the researchers proposed a mitigation process;
- Best practices/ success factors when the researchers collected the criteria from successful cases;
- 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% of challenges/ barriers, 31% of best practices/ success factors, and 11% of risks and threats. We present some of these in the central studies summary in the following subsection, as shown in Table B.3.

2.1.2.2 The central studies summary

This subsection shows the most cited documents and those that contributed with more attributes. 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. We begin with central studies.

The most cited document in the SLR was made by Nidhra *et al.* (2013), providing 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.* (2015), summarizes empirical evidence on the impact of global dispersion dimensions on coordination, team performance, and project outcomes. This study consistently conceptualized the global dispersion dimensions but quantified them in many different ways. Further, the study reveals that geographical and temporal dispersion is associated with a distinguished set of coordination challenges like impact on task resolution time, software quality, and objective team performance.

Following the experience of 10 years of GSD at Philips made by Kommeren e Parviainen (2007), 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.* (2015), the second paper most cited.

In sequence, Richardson *et al.* (2012) 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 composed of 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 ten 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.* (2019). They made an SLR to determine the factors affecting GSD communication, then classified it into eight categories and proposed a conceptual framework. They then made a questionnaire with 202 responses, and through multivariate analysis, the Partial Least square-structural equation model validated the framework proposed. The authors defined every 44 issues collected precisely, one vulnerable point in many documents, reported in the last subsection.

Subsequently, Iqbal *et al.* (2022) contribute with 42 attributes. The authors propose a Requirements Engineering Practices (REP) model to address the common issues in Software Development Outsourcing (SDO). Therefore, they did a Root Cause Analysis and five workshops with 60 Man-hours spent, where 89 root causes were discovered for the 43 common issues of the SDO RE process. Additionally, by applying the brainstorming technique, 124 relevant REP have been identified and suggested to suppress the 89 root causes and deal with 43 common issues of the SDO REP.

The third research that most contributed was Gulzar *et al.* (2018), with 40 attributes collected. Before interviewing software development teams, they made an online questionnaire to collect the critical situational factors in global software project management. Then, through a Fuzzy Analytic Hierarchy Process, they categorized and prioritized the situational factors. The authors conclude that the Trust group is the primary criterion influencing project development.

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

2.1.2.3 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.

In these ten Tables 2.7, 2.8, 2.9, 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, and 2.16 we show the complete Criteria list for contracting professionals in GSD context. In sequence by criteria code, we present all the criteria lists for contracting professionals in GSD tables. We organized these Tables with the first column of presents the criteria code, the second column showing the criteria name and the definition in sequence, and the last column displaying the number of citations and their percentage.

Consequently, to have statistical analyses of the SMART indicators (See Table 2.5 - Grouping the criteria as a SMART indicator, and Table 2.6 - Definition of the SMART indicator group types) and the criteria, we use the "dummy encoding" or "one-hot encoding" to calculate their correlation. Table 2.17 - SMART indicator group types correlation, show the numbers of criterion collected "n", Pearson correlation, and P-Value.

Nevertheless, we did not compute the correlation of the groups Indirect x Direct and Subjective x Objective because they are opposite, so they had an entirely negative Pearson correlation coefficient (-1.0). The group Objective x Direct presents a strong positive correlation coefficient (0.788), mainly because of their description in the group Specific and Achievable; they tend to be similar. On the other hand, the group Quali-quanti x Qualitative and Inside x Both also present a strong Pearson correlation coefficient but negative (-0.854, and -0.802), generally because they tend to be the opposite of each other. Next, the groups with moderate negative correlation coefficients were Qualitative x Direct (-0.594) and Qualitative x Objective (-0.649) because if the criterion is "direct" and "objective", it tends to be "quali-quanti" or "quantitative", as we can see in the correlations of groups Quali-quanti x Direct and Quali-quanti x Objective with moderate positive correlation coefficient (0.468, and 0,482), with p-value zero.

Afterward, we emphasize the fourteen 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. 2.3 - Top 14 highly cited criteria in the SLR.

Furthermore, the criteria most cited in the SLR are soft skills instead of hard skills. Whereas the hard skills relate to the computer science subject's bases, the soft skills are behavioral as social, organizational, teamwork, collaborative, communication, and project-based skills (HIDAYATI *et al.*, 2020). Hence, in the GSD context, where we could have teamwork persons from everywhere, soft skills are more critical than hard skills, mainly because it is more challenging to recognize soft skills than hard skills in a worker selection process.

We assembled the word cloud using all the abstract words, as shown in Fig. 2.4 -

Table 2.7 – Criteria list for contracting professionals in GSD - 1/10

Code	Criteria	Description	Cited*
C001	Communication	Communication is the biggest challenge for GSD due to the need for adequate and proper ways of communication in general. In addition, the reduced communication frequency with the project team members became a problem due to the need for more informal or face-to-face contact (AMMAD *et al.*, 2019; VIZCAÍNO *et al.*, 2019).	33 (51%)
C002	English domain	The different language usage among distributed team members. The English language has been widely used as a professional language at national and international platforms (AVRITZER *et al.*, 2014; AMMAD *et al.*, 2019).	19 (29%)
C003	Cultural differences among teams	Each culture has its standards, styles, and moral principles, which can provoke communication-related issues when individuals from different cultural backgrounds communicate with another one (AMMAD *et al.*, 2019).	27 (42%)
C004	Temporal issues	Temporal issues are related to the time difference between teams that work in several remote locations. Delayed feedback and responses are problematic and restrict the possibility of synchronous interaction, cooperation, and confidential assessment. This criterion is related to the geographic dimension (NGUYEN-DUC *et al.*, 2015; AMMAD *et al.*, 2019).	22 (34%)
C005	Fear impact	Fear's impact can manifest itself in numerous ways, including the desire to prevent or limit communication with remote colleagues. In some instances, the objective can be to hinder the work of these remote colleagues directly (RICHARDSON *et al.*, 2012).	2 (3%)
C006	Employee Satisfaction	In GSD, the work typically is outsourced or offshore, so it is equally challenging to be motivated, cooperative, and supportive of remote colleagues who are often seen as on the brink of replacing them. These issues negatively impact team members' motivation levels. Thus, this became a human resource problem (RICHARDSON *et al.*, 2012).	5 (8%)
C007	Trust building	Personal or impersonal, including cognitive trust, refers to beliefs about others' competence and reliability. This can lead individuals to engage in less self-protective actions and be more likely to take risks (GOPAL *et al.*, 2018; VIZCAÍNO *et al.*, 2019; HUMAYUN; CUI, 2013).	28 (43%)
C008	Degree of cooperation	Collaboration among distributed teams. Numerous issues directly mitigate against establishing cooperation in the global team environment. In these circumstances, cooperation between team locations must be developed, established, and effectively managed from the project management perspective to avoid the reluctance to share information(RICHARDSON *et al.*, 2012; AKBAR *et al.*, 2020a; NIDHRA *et al.*, 2013).	14 (22%)
C009	Precise cost estimation	While transferring knowledge from client location to offshore location, the knowledge transfer takes a long time and requires more iterations. It isn't easy to measure how much cost it must invest for knowledge transfer. (NIDHRA *et al.*, 2013; AKBAR *et al.*, 2020b).	10 (15%)
C010	Effective leadership	The teams may be formed without planning, lacking the required knowledge and skills. Skilled leadership that has the expertise to assess and analyze the impact of demanded changes and will make the right decision at the right time. Lack of integration planning and lack of management. An effective integration plan is necessary for all Global Software Development projects, especially for a large ones, to be successful at the integration stage(ILYAS; KHAN, 2017; AKBAR *et al.*, 2020b).	14 (22%)
C011	Project failure risk	There are micro and macro-risk elements. Micro-risks can often be correctly determined, and alternative strategies put in place to mitigate their potential impact. Macro-risks, on the other hand, may not even be considered. It is important to analyze the need and the root cause of change(RICHARDSON *et al.*, 2012; AKBAR *et al.*, 2020b).	5 (8%)
C012	Defined of roles and responsibilities	Defined roles and responsibilities are essential to assign the proper responsibility and task to the right person and time and should be clearly defined, articulated, and effectively disseminated for all team members (RICHARDSON *et al.*, 2012; AKBAR *et al.*, 2020b).	16 (25%)
C013	Technical requirements	We must base the selection of global team members on the project's technical requirements. Therefore, the Project Manager needs direct access to information about the academic and technical skills and experiences of potential team members (RICHARDSON *et al.*, 2012).	2 (3%)
C014	Effective Partitioning	Effective task partitioning between team members and sites can be modularized, phased, or integrated. The selection often depends on the nature of the work or the physical location of specific tools or skill sets (RICHARDSON *et al.*, 2012).	2 (3%)
C015	Team Skills Database	All global team members' technical capability and skill levels must be available to the Project Manager to facilitate effective global team operation. In addition, this information needs to be efficiently maintained, understood, and easily accessible. It is a human resource dimension (RICHARDSON *et al.*, 2012).	1 (2%)
C016	Knowledge interchange rate	Knowledge interchange rate is a process of exchange of explicit or tacit knowledge between two agents, during which one agent purposefully receives and uses the knowledge provided by another (AMMAD *et al.*, 2019; GOPAL *et al.*, 2018).	20 (31%)
C017	Coordination challenges level	Team coordination is defined as activities required to maintain consistency within a work product or to manage dependencies within the workflow. There are many different types of dependencies between task and task holders. These dependencies lead to a need for coordination among stakeholders working on a related set of tasks. When these coordination needs are not satisfied, they will have coordination challenges(RICHARDSON *et al.*, 2012; AMMAD *et al.*, 2019).	26 (40%)
C018	Transparency of roles and responsibilities	It is important to assign the right task and responsibilities to the relevant person. The roles and responsibilities need to be clearly articulated and understood by all the relevant parties(RICHARDSON *et al.*, 2012; AKBAR *et al.*, 2020b; SHAMEEM *et al.*, 2020).	6 (9%)
C019	Reporting requirement	Clear software requirements are compulsory for the quality product and it changes till the completion of software development gradually, changes create new challenges to deal with. Requirements must be discussed again and again to achieve a unified interpretation, resulting in optimal designs and software components which can be smoothly integrated(KOMMEREN; PARVIAINEN, 2007; HASSAN *et al.*, 2019).	10 (15%)
C020	Relevant information disclosure	Information Management is critical due to sharing relevant information between team members. Distance negatively impacts information dissemination. The loss of face-to-face contact and the need to rely on asynchronous communication all impact the level and quality of available and transmitted information between sites (RICHARDSON *et al.*, 2012).	4 (6%)
C021	Team issues	Within the global team context, there is a clear need to develop a one-team approach. Teamwork is based on team-member relationships that facilitate the development of mutual respect and trust. This leads to developing a cohesive motivated team that sees itself as a single unit regardless of its members' location(RICHARDSON *et al.*, 2012; VIZCAÍNO *et al.*, 2019).	19 (29%)
C022	Process Management	A process that directly addresses the specific requirements of the global team environment needs to be developed and implemented. Adequate training on the process operation should be provided to all team members. Shared ownership of the process should be fostered between team members across locations(RICHARDSON *et al.*, 2012; AKBAR *et al.*, 2020b).	6 (9%)
C023	Software support tools	Tools and technology to facilitate knowledge transfer within the teams. Many organizational practices and technological tools are used during the knowledge transfer process. These tools aim to increase the focal area's knowledge to a high level of knowledge that allows for solving problems and innovation(NIDHRA *et al.*, 2013; RICHARDSON *et al.*, 2012; KHAN *et al.*, 2019; GOPAL *et al.*, 2018).	12 (18%)
C024	Technical support	The technical issues comprise all the challenges associated with the technology used to initiate communication among distributed team members. This problem could cause hindrance and misunderstanding (AMMAD *et al.*, 2019; RICHARDSON *et al.*, 2012).	3 (5%)
C025	Communication Tools	Quality of communication tools and network speed between sites. A good selection of synchronous and asynchronous communication tools should be provided. An essential aspect of the provision of such tools is to ensure staff are motivated and trained to leverage their capabilities [L26] [L37] [L94]	6 (9%)
C026	Proficiency in a programming language	Proficiency in a programming language and expertise and knowledge in the application domain. High proficiency in a programming language to build codes with complex instructions. It is a personal technical dimension (LAMERSDORF *et al.*, 2012; HIDAYATI *et al.*, 2020).	6 (9%)
C027	Experience in similar projects	Staff experience on similar projects, programming language, and tool experiences (LAMERSDORF *et al.*, 2012).	4 (6%)
C028	Use of software tools	Evaluating and selecting software packages that meet an organization's requirements is a complex software engineering process. Selection of the wrong software package can be costly and adversely affect business processes (JADHAV; SONAR, 2009).	1 (2%)
C029	Contribution to team effort	A team's effort contribution is the participation in helping each other, mutual support of team members, suggestions, and contribution of teams on project outcomes (GOPAL *et al.*, 2018).	3 (5%)
C030	Accomplishment of assigned responsibilities	Demonstrates initiative and responsibility for individual performance to get the job done under direct supervision (NEBRASKA–LINCOLN, 2022).	2 (3%)
C031	Task efficiency	Task efficiency is the completion of assigned or agreed-upon responsibilities is the critical behavior of completing assigned tasks in a timely and efficient manner (NEBRASKA–LINCOLN, 2022).	2 (3%)
C032	Tasks effectiveness	Task effectiveness is significant because the uncertainty on product and technological novelty requires more design and development tasks to be completed on time, avoiding the increasing lead time uncertainty (SWINK, 2003).	1 (2%)
C033	Independence of thought and action	Independence of thought and action is the person who applies critical thinking work to develop fairness, insight into the personal and public level, humble intellect and postponing the crisis, spiritual courage, integrity, perseverance, self-confidence, and research interest (YILDIRIM; OZKAHRAMAN, 2011).	2 (3%)
C034	Creativity in approach to problem-solving	Creativity in problem-solving is capturing and getting inspired by external success stories (GOYAL; GUPTA, 2020).	1 (2%)
C035	Scientific attitude	The scientific attitude is a willingness to change one's theory in the light of new empirical evidence critically. This attitude is a community ethos, not a psychological trait of individual scientists (MCINTYRE, 2019).	1 (2%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.8 – Criteria list for contracting professionals in GSD - 2/10

Code	Criteria	Description	Cited*
C036	Determination and effort	The effort reflects the effort exerted by the participant to complete the task, while exertion reflects the overall perception of strain caused by the task. The perceptual sensations represent three dimensions of perceived effort (sensory-discriminative, motivational-affective, and cognitive-evaluative dimensions) (HUTCHINSON; TENENBAUM, 2006).	1 (2%)
C037	Contributing to discussions	It is common for passive participants to doubt their abilities to contribute to discussions and instead believe they will do more good by remaining silent. On the other hand, individuals will be more likely to transition to posters when they feel sufficiently secure that they will receive positive responses and add value to the group (AMICHAI-HAMBURGER *et al.*, 2016).	1 (2%)
C038	Accepting criticism gracefully (personality dimensions)	Instill the values of good human relations and the need to work cooperatively, accept criticism gracefully, be courteous and enthusiastic, and maintain friendly relationships. It is related to personality dimensions (CRAMER, 1965).	1 (2%)
C039	Communicate clearly with team	Communicate clearly with team members when speaking and writing. Understand the direction of the team (MOURTOS, 2012).	1 (2%)
C040	Communicate civility with team	In a team context, civility is acting with empathy, compassion, and kindness in every interaction and treating everyone connected online with dignity and respect (SLITER, 2022).	1 (2%)
C041	Communicate clearly with stakeholders	Communicate clearly with stakeholders when speaking and writing. Understand the direction of the stakeholders (MOURTOS, 2012).	1 (2%)
C042	Communicate civility with stakeholders	In a stakeholders context, civility is acting with empathy, compassion, and kindness in every interaction and treating everyone connected online with dignity and respect (SLITER, 2022).	1 (2%)
C043	Collaborative work friendly	Collaborative work friendly is the ability to function on multidisciplinary teams. In today's multicultural world, this outcome also implies an ability to collaborate with people from different cultures, abilities, and backgrounds (MOURTOS, 2012).	2 (3%)
C044	Culture of leadership	Employees desire good error management, forms of participation, and a culture of leadership that includes support and the establishment of common mindsets, stability, and reliability of corporate values (KLUGE *et al.*, 2020b; KHAN *et al.*, 2019).	9 (14%)
C045	Comprehension ability	Comprehension ability in a project context depends on information about the trustee's roles and type of experience with technology use. Therefore, the personal profile also provides more data about skills and knowledge, such as previous work experience and academic studies. This information will allow the trustor to perceive a trustee's capabilities rapidly and explicitly (VIZCAÍNO *et al.*, 2018).	2 (3%)
C046	Assignment of roles and responsibilities	Clear assignment of roles and responsibilities. The roles and responsibilities of the team members must be clearly defined, which is vital for controlling and managing misconceptions during the implementation of process activities (AKBAR *et al.*, 2020a; KAMAL *et al.*, 2020).	3 (5%)
C047	Transparency of Vision and goal	Vision and mission of demanded changes, knowing the scope and purpose of change management is important for the successful implementation of the requested changes (KAMAL *et al.*, 2020; AKBAR *et al.*, 2020a; GOPAL *et al.*, 2018).	8 (12%)
C048	Team training and monitoring	Types of training: Induction Program, Training on Application Functionality, On the job Training, Trainee ramp-up. The education and support to distributed team members are essential in GSD (AKBAR *et al.*, 2020b; SUNDARARAJAN *et al.*, 2019).	7 (11%)
C049	Geographically distributed CCB (change control block)	Tracking, monitoring, and controlling the Requirements change management activities in the offshore software development environment. We should establish a geographically distributed CCB (change control block) to verify and determine the reasoning behind the requested changes (KAMAL *et al.*, 2020; AKBAR *et al.*, 2020b).	2 (3%)
C050	Resistance management of changing	The political environment influences the management effect of organizations on the requirements to change the management process because some organizations are hesitant to change the requirements. However, resistance management is essential in eliciting the desired requirements and effectively (KAMAL *et al.*, 2020).	1 (2%)
C051	Strong team relationship	The arduous relationship among team members (global service climate). The relationships of overseas team members should be formalized to share and accommodate secret requirements and build trust (KAMAL *et al.*, 2020; KHAN *et al.*, 2019).	7 (11%)
C052	Skilled human resources	Skilled human resources are the types of skills or expertise of individuals available. Skilled human resources is a team core consideration in the agile software development paradigm and are essential for successfully implementing requested requirements. Thus, this is the knowledge, skills, and attitudes of a human resource department (KAMAL *et al.*, 2020).	5 (8%)
C053	Response/ feedback online	The delay in getting a response can expand the time needed to resolve the issues. It is perceived as difficult and annoying for the teams working remotely in different time zones. It might also be a major issue in globally distributed development because team members are unable to analyze the overall project procedure due to delay in response or feedback (AMMAD *et al.*, 2019).	4 (6%)
C054	Requirement and data traceability	Traceability of data is a key issue Working in a heterogeneous data environment. Traceability can only be assessed by checking the quality and quantity of links among related data resources from different software tools (RAFI *et al.*, 2020b).	9 (14%)
C055	Process awareness	The organizational management must provide training and certification opportunities to Requirements change management team members. It is much more important to hold workshops and seminars to motivate the team members to participate in process awareness (AKBAR *et al.*, 2020b).	6 (9%)
C056	Formal standard and procedures	The practitioner should adopt formal standards and procedures for success. The team members should use formal processes, frameworks, and best practices. The standards and procedures guide the practitioners about "what to do" and "how to do it."(AKBAR *et al.*, 2020b; AKBAR *et al.*, 2020a).	4 (6%)
C057	Change acceptability	The identification of change is the key activity, which indicates why, how, and when change is needed. The "change acceptability" refers to the quality of a software project dependent upon the satisfaction of the customers' needs and expectations. However, the acceptance of requirement changes during software development is a positive mark towards the satisfaction of customers (AKBAR *et al.*, 2020b; KOMMEREN; PARVIAINEN, 2007; AKBAR *et al.*, 2020a).	10 (15%)
C058	Continuous organizational support	An organizational commitment can be triggered by a combination of three conditions: desire, compulsion, and obligation to work for the focal organization. Commitment provides a foundation for employees to engage in behaviors that support the organization (SANDA; KUADA, 2016).	4 (6%)
C059	Frequency of social events	Social events include but are not limited to telling people what to do, spending time with sharp and witty people, giving speeches, attending parties, laughing without reservation, voicing strong personal values and opinions in a group, telling jokes, criticizing someone, and asking for help or advice (KASHDAN *et al.*, 2008).	2 (3%)
C060	Task synchronization	Reduced opportunities for synchronous communication were also significant risk factors in GSD. Due to the temporal distance, the use of synchronous communication becomes less. Using asynchrony communication tools for communication and collaboration practices can be unsafe. There might be a probability of an unnoticed or lost email, so an individual has confusion which increases the likelihood of misunderstanding (AMMAD *et al.*, 2019).	6 (9%)
C061	Software testing methods	Components are delivered untested due to pressure caused by time constraints on the development teams. They should be properly unit tested before integrating them into the final system as they are developed for some specific use cases. In almost 80% of the projects, the integrator finds defects during integration due to improper unit testing (ILYAS; KHAN, 2017; HASSAN *et al.*, 2019).	9 (14%)
C062	Geographical dimension	Geographical distance is geographic dispersion between team members in remote sites. Communication risk increases whenever geographic distance increases. Therefore, this criterion is related to the geographic dimension (AMMAD *et al.*, 2019; NGUYEN-DUC *et al.*, 2015).	16 (25%)
C063	Organizational dispersion	Overseas site's response. In GSD, the development sites are located across several geographical locations in different time zones. The difference in team identity. The difference in organizational objective and strategy. Information misinterpretation due to repeatedly readjusting to a variety of methods. Frequently readjusting to alternative methods of their business units. Loss of tacit knowledge due to the replacement of onshore with offshore staff. Delay due to staff changes [L06, L09, L69].	7 (11%)
C064	Turnover (team/staff)	The high rate of skilled employee turnover or staff changes lead to the organization's loss of tacit knowledge. These changes result in additional delays and conflicts in the development process. In addition, change in staff will create gaps in the knowledge transfer process and leave developers to work independently (NIDHRA *et al.*, 2013).	2 (3%)
C065	Degree of novelty	Degree of the novelty of the product for involved persons. Novelty increases the difficulties in a project. When the requirement is changed or is new, team members might be unaware of new requirements or team members might not understand the requirements completely. If the higher the novelty of project knowledge, the more difficult it is to transfer knowledge (NIDHRA *et al.*, 2013; LAMERSDORF *et al.*, 2012).	6 (9%)
C066	New vendor relationship	The client's knowledge loss becomes a problem of knowledge transfer when the company moves from an old vendor relationship to a new vendor relationship, as the client no longer holds all the information that the new vendor critically needs to involve in services with the client (NIDHRA *et al.*, 2013).	1 (2%)
C067	Updated Knowledge transfer documents	When the knowledge's codifiability is higher, the knowledge can be easily transferred to knowledge recipients. In some cases, employees need help finding updated knowledge transfer documents in their project repository, leading to delays in project delivery (NIDHRA *et al.*, 2013).	1 (0%)
C062	Geographical dimension	Geographical distance is geographic dispersion between team members in remote sites. Communication risk increases whenever geographic distance increases. Therefore, this criterion is related to the geographic dimension (AMMAD *et al.*, 2019; NGUYEN-DUC *et al.*, 2015).	16 (25%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.9 – Criteria list for contracting professionals in GSD - 3/10

Code	Criteria	Description	Cited*
C063	Organizational dispersion	Overseas site's response. In GSD, the development sites are located across several geographical locations in different time zones. The difference in team identity. The difference in organizational objective and strategy. Information misinterpretation due to repeatedly readjusting to a variety of methods. Frequently readjusting to alternative methods of their business units. Loss of tacit knowledge due to the replacement of onshore with offshore staff. Delay due to staff changes [L06, L09, L69].	7 (11%)
C064	Turnover (team/staff)	The high rate of skilled employee turnover or staff changes lead to the organization's loss of tacit knowledge. These changes result in additional delays and conflicts in the development process. In addition, change in staff will create gaps in the knowledge transfer process and leave developers to work independently (NIDHRA *et al.*, 2013).	2 (3%)
C065	Degree of novelty	Degree of the novelty of the product for involved persons. Novelty increases the difficulties in a project. When the requirement is changed or is new, team members might be unaware of new requirements or team members might not understand the requirements completely. If the higher the novelty of project knowledge, the more difficult it is to transfer knowledge (NIDHRA *et al.*, 2013; LAMERSDORF *et al.*, 2012).	6 (9%)
C066	New vendor relationship	The client's knowledge loss becomes a problem of knowledge transfer when the company moves from an old vendor relationship to a new vendor relationship, as the client no longer holds all the information that the new vendor critically needs to involve in services with the client (NIDHRA *et al.*, 2013).	1 (2%)
C067	Updated Knowledge transfer documents	When the knowledge's codifiability is higher, the knowledge can be easily transferred to knowledge recipients, and in some cases, employees need help finding updated knowledge transfer documents in their project repository, leading to delays in project delivery (NIDHRA *et al.*, 2013).	1 (0%)
C068	Knowledge Codifiability	Knowledge codifiability in an organizational project repository happens when complex knowledge is not codified in a high-level manner and is not straightforward to understand (NIDHRA *et al.*, 2013).	1 (2%)
C069	Proper documentation	The root cause of most integration problems is inadequate documentation. Many project documentation is hard for the client organization because most of the knowledge concentrates and remains hidden in the vendor organization. In some cases, even if the documentation exists, it is obsolete and plays no role other than introducing new people to the coarse grain (ILYAS; KHAN, 2017).	6 (9%)
C070	Compatibility of data	Lack of compatibility. The GSD teams may use diverse platforms and tools to develop software components or subsystems. These components/subsystems raise compatibility problems during integration. Data integration, this request for integration implies that all the development artifacts in software processing are constantly accessible, even if they reside across different development tools (ILYAS; KHAN, 2017; RAFI *et al.*, 2020b).	6 (9%)
C071	Appropriate architecture	The development, maintenance, and evolution of software architecture appear to be crucial, especially concerning the definition of interfaces. Lack of continuous and active management of the architectures, including change control with a representation of all parties involved, is likely to lead to major problems, which appear to be detected only during the integration stage of the project (ILYAS; KHAN, 2017; KOMMEREN; PARVIAINEN, 2007).	6 (9%)
C072	Similar programming languages	In GSD, many software components are not properly integrated due to the heterogeneity of software programming languages, operating systems, and communication tools. In addition, a common infrastructure is not shared between sites, making integrating components developed on these sites complex (RAFI *et al.*, 2020b; ILYAS; KHAN, 2017).	3 (5%)
C073	Product selection and customization (off the shelf)	Due to time and budget constraints, selecting a proper component and customization from a large pool of components is challenging. Furthermore, in the case of open-source software (OSS), there are problems in the selection, maintenance, integration, and licensing of OTS(off-the-shelf) components (ILYAS; KHAN, 2017).	1 (2%)
C074	Availability of human resources	Lack of human resources, knowledge, and skills. Lack of suitable infrastructure for integration and the nonavailability of skilled human resources to solve integration issues in time hinder the integration process. This criterion is related to a human resources department issue (ILYAS; KHAN, 2017; HASSAN *et al.*, 2019; KLUGE *et al.*, 2020b).	14 (22%)
C075	Proper component interfaces	Lack of proper component interfaces is the interface through which a component requests services or provides services. Inconsistencies between components/modules create problems during the integration stage (ILYAS; KHAN, 2017).	1 (2%)
C076	Relationship between person at different sites	Lack of employee respect issues. Has the team met or talked personally? This event grows the relationship between people at different sites, increasing the efficient outsourcing relationships in organizational management (HUSSAIN *et al.*, 2021; MONASOR *et al.*, 2012; LAMERSDORF *et al.*, 2012).	4 (6%)
C077	Common working experience	The common work experience is the site's experience working together; or the number of hours worked together by each team, depending on the project program objective (LAMERSDORF *et al.*, 2012; MONASOR *et al.*, 2012).	2 (3%)
C078	Criticality of the task	Criticality is the importance of getting the task done correctly in terms of its adverse effects should problems occur, and a critical task is one where a failure impacts the life of a human (CHANSEAU *et al.*, 2019).	1 (2%)
C079	Complexity of the task	Complexity is a function of the number of interconnected variables in the task, and the most challenging tasks are those in which there is a constraint on decomposition into simpler subtasks (HALFORD *et al.*, 2007).	1 (2%)
C080	Degree of Task formality description	The degree of task formality description is the role of methodology (techniques, graphs, formulas) to perform or explain professional services. Also, formality controls workplace relationships between professionals within organizations, allowing greater or lesser professional self-sufficiency (MIEG *et al.*, 2013)	1 (2%)
C081	Process phase (lifecycle)	The process phase (lifecycle) comprises the development, distribution, acquisition, deployment, use, maintenance, deactivation, and disposal phases (DICK; NAUMANN, 2010).	1 (2%)
C082	Degree of collaborative task coupling	Collaborative coupling, in broad terms, signifies the intensity of user-user interaction to accomplish a task. Collaborative task coupling is categorized into loosely coupled and tightly coupled (SIGITOV *et al.*, 2019).	2 (3%)
C083	Degree of Business Process maturity	If there are no stable requirements and requirement changes, this change has to be communicated. This is not easily possible if there is no maturity or no good communication infrastructure between sites (LAMERSDORF *et al.*, 2012; GULZAR *et al.*, 2018; YASEEN *et al.*, 2016).	5 (8%)
C084	Product size	The product size to be developed comprise program code, an integral component of the software; architectural design size: components, their functions, and their interactions (interfaces); and specification size like the Unified Modeling Language (ZHAO, 2021).	3 (5%)
C085	Stable requirements	The high degree of requirements changes during the project may provoke significant delays, with a good chance of introducing errors and misunderstandings. The impact of unstable requirements is generally high for any software development project (LAMERSDORF *et al.*, 2012; KOMMEREN; PARVIAINEN, 2007).	7 (11%)
C086	Number of involved sites	In global software development, it is necessary to observe the number of involved sites that needs to collaborate on a project (LAMERSDORF *et al.*, 2012).	1 (2%)
C087	Time pressure	Pressure on people working on the project (LAMERSDORF *et al.*, 2012) results in developers attempting to find shortcuts and adopt different approaches to complete software development to accomplish the given deadline (HASSAN *et al.*, 2019).	4 (6%)
C088	Learning curve	Learning to work together, master the domain, and understand mutual sub-domains may take years. This fact may result in underestimating the learning curve in multi-site software development. It is a personal technical dimension (KOMMEREN; PARVIAINEN, 2007).	2 (3%)
C089	Integration plan	A clear integration plan is necessary to ensure efficiency and without extra complexity when finally putting the system together. Thus, integration asks for a centrally controlled approach (KOMMEREN; PARVIAINEN, 2007).	4 (6%)
C090	Vision for the end product	Distributed members must be aware of the rules and regulations they must observe during the project, and a shared vision for the project can align team members toward shared goals (MOHAPATRA *et al.*, 2010).	1 (0%)
C091	Overloading of key personnel	Because various initiatives compete for the same employees, a possible lack of resources appears (such as overloading of crucial personnel, unavailability of experts, and unavailability of the necessary training), which may lead to failure in the project not going according to the plan (**??**).	1 (2%)
C092	Consistent data	The software development team must know the data's status before using it in the deployment phase to make data more consistent since continuous deployment leads all importance towards the development of the process, which causes errors and inconsistency in data (RAFI *et al.*, 2020b).	1 (0%)
C093	Misspelling in data entry	The development and operation teams working together in a DevOps environment may adopt best practices to resolve data entry issues avoiding misspellings in data entry. Thus, to validate the performance of product efficiency, data must counter checked to resolve such issues (RAFI *et al.*, 2020b).	1 (0%)
C094	Missing information	The critical challenge in the DevOps environment is missing information and other invalid data due to integrating different sites in a software organization. This hindrance can be resolved by automated data validation processes or by adopting lean in the development and operational environment (RAFI *et al.*, 2020b).	1 (0%)
C095	Data Harmonization	The increasing demand to integrate sizeable open data sets, ongoing updates, visualization, and analysis while addressing privacy and security concerns are common problems. Hence, to support data harmonization, developing end-to-end automated processes will result in low-quality data products [L44].	2 (3%)
C096	Data visualization tools	Visualization of data it can be claimed that, without suitable visualization and understanding of large integrated data sets in a heterogeneous data environment, it is critical day by day to understand the purpose of data (RAFI *et al.*, 2020b).	1 (0%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.10 – Criteria list for contracting professionals in GSD - 4/10

Code	Criteria	Description	Cited*
C097	Data aggregation	Data Aggregation is one of the critical challenges in the mining process; data searched, reported, and presented from a different source is vital to gain specific business objectives. Therefore, a consistent approach is required to present and aggregate data (RAFI *et al.*, 2020b; GOPAL *et al.*, 2018; AMMAD *et al.*, 2019).	3 (5%)
C098	Measuring provenance of data	Data provenance means the location of specific data and when and where that data was generated. Data comes from multiple sources, causing reliability challenges in heterogeneous data environments. Therefore, integrity and authenticity must be assessed when analyzing data (RAFI *et al.*, 2020b).	1 (0%)
C099	Storage of transition logs	Storage of transition logs while considering data validity and security, storage of transition logs is a challenge in a DevOps environment (RAFI *et al.*, 2020b).	1 (2%)
C100	Analyze Data in Real Time	Data generated in real-time, i.e., online development systems, must check data assessment while sharing data in a continuous environment of DevOps during production (RAFI *et al.*, 2020b), and proper tools are required to maintain continuous scalability and performance measures for better release (RAFI *et al.*, 2022).	3 (5%)
C101	New visualization techniques and their assessments	New visualization techniques and their assessments to implement or integrate new techniques with the existing system must follow all privacy guidelines suggested by developers. Thus, if appropriately implemented with whole team discussion, such tools may help reduce time and cost (RAFI *et al.*, 2020b).	1 (2%)
C102	Contract management	A contract is an agreement that creates obligations for the parties. Contract management involves building a good working relationship between client and contractor. It involves proactively anticipating future needs and reacting to situations or risks that may arise during the contract execution (PMI, 2021; ARROWSMITH *et al.*, 2000).	3 (5%)
C103	Task updating	Managers are confronted with their entire teams working from different locations. Also, it has to agree on individual working patterns and work schedules with employees to accommodate their care responsibilities by effectively communicating realistic expectations and setting achievable deadlines considering the highly unusual context in which teleworking currently takes place while ensuring business continuity and the required level of performance (ORGANIZATION, 2020).	4 (6%)
C104	Quality assurance procedure	Lack of detailed requirements specification documentation for global teams. Evaluating the project quality concerning the service (GOPAL *et al.*, 2018; ILYAS; KHAN, 2012).	7 (11%)
C105	Incremental integration	In incremental integration, pieces of software are integrated into increments to avoid extensive integration. Thus, if we set an initial stage for the integration of components, while some components may still be in the development stage, it may be more valuable and save precious time during later stages of integration (ILYAS; KHAN, 2015).	2 (3%)
C106	Regular deliveries	Agile software development brings its own set of novel challenges that must be addressed to satisfy the customer through the early and continuous delivery of valuable software (MONIRUZZAMAN; HOSSAIN, 2013).	4 (6%)
C107	Use of modular approach	In an Agile software project, the modularization approach segregates the code base into domain modules, identifies well-defined interfaces to these modules, and restricts the inter-module interactions through these interfaces (SARKAR *et al.*, 2009).	3 (5%)
C108	Cross-functional teams	Each team member, representing a different knowledge specialty, comes to a team with a different thought world so that each member understands the problem, critical elements, and steps in solving the problem differently from each other. These differences create a lack of common ground, resulting in problems of information exchange, interpretation, and attribution (MAJCHRZAK *et al.*, 2012).	3 (5%)
C109	Expert area (prior experience)	The prior experience measures the number of team programmers who have participated in at least one similar project. Therefore, the level of uncertainty is expected to decrease as the number of team members with relevant experience increases (GOPAL *et al.*, 2002).	2 (3%)
C110	Scrum expertise	Having previous experience in the roles, practices, processes, procedures, and artifacts in Scrum (HIDAYATI *et al.*, 2020).	2 (3%)
C111	Scrum hours	Scrum is the most widely applied Agile methodology and is a process framework for delivering products and services of the highest possible quality and handling complex problems or situations. Iterative and incremental approaches are used to develop products using cross-functional teams (HIDAYATI *et al.*, 2020).	1 (2%)
C112	Number of sprints	The number of sprints are short work cycles for incremental development (HIDAYATI *et al.*, 2020).	1 (2%)
C113	Analytical thinking	Analytical thinking is a personal soft skill where the developer is highly proficient in a software programming language to build codes with complex instructions. Analytical thinking is a behavior required to support the success of highly active projects in global software development. It is a personality dimension (HIDAYATI *et al.*, 2020).	1 (2%)
C114	Time management	Time management planning is a practice where people plan what they intend to accomplish and when on a given day. How do people specifically engage, or how is technology involved with time management planning? (LUND; WIESE, 2021).	3 (5%)
C115	Conflict management	Conflict management could be divided into affective and substantive conflict. Affective conflict implies emotional clashes between individuals based on selfish or personal issues. Substantive conflict involves rational differences based on the content of the ideas or issues (COWGER, 1980).	5 (8%)
C116	Flexibility	Flexibility is adjusting one's leadership style, method, or approach in response to different or changing contextual demands to facilitate group performance (KAISER; OVERFIELD, 2010).	3 (5%)
C117	Handling stress	The behavioral paradigm characteristically defines stress in terms of stimulus-response connections. Stress can be described as the stimulus or force that, if sufficiently strong, can cause tension in the individual who experiences it. We can better comprehend stress by exploring the circumstances or context (i.e., occupational or personal) surrounding the events (LAFROMBOISE; ROWE, 1983).	1 (2%)
C118	Problem solving	The problem-solving ability or the inability to see the problem arises due to the uncooperative motivational attitude of higher-ranking management interacting with the team members at remote sites, resulting in a lack of team cohesiveness (AMMAD *et al.*, 2019).	3 (5%)
C119	Diplomacy	Diplomacy comes from the intercultural competence of specialists, i.e., the formation of practical skills and abilities that ensure the ethnocultural perception of the individual development and his/her ability to correctly interpret specific manifestations of verbal and nonverbal behavior in different ethnic cultures (BILETSKA *et al.*, 2021).	1 (2%)
C120	Interfacing with different layers of development framework	If an application has to maintain persistent data, a mechanism for allowing it is required. CRUD pattern could be used to maintain a database and manage the life cycle of creating, updating, deleting, and reading data. In addition, it is essential for modeling related entity classes (MONTE-MOR *et al.*, 2011; HIDAYATI *et al.*, 2020).	3 (5%)
C121	Code coverage concepts and tools	Code coverage measure the degree to which a test suite exercises a software system. Software testing is often used to determine and sometimes improve software quality. However, it is also very labor, and resource-intensive process that often accounts for more than 50% of the total cost of software development (YANG *et al.*, 2006).	2 (3%)
C122	Refactoring concepts	Refactoring is constantly improving the design of existing code without modifying the fundamental behavior. For example, in Agile, teams maintain and enhance their code on an incremental basis from Sprint to Sprint. In addition, refactoring enables simplifying unclear and complex code (WILLIAMS, 2010).	1 (2%)
C123	Code-smell concepts	A code smell is a term commonly used to describe potential problems in software design (SANTOS *et al.*, 2018).	1 (2%)
C124	Religion and political attitudes	Somehow, personal religion and political factors and behavior also relate to inter-culture as every country has its law, rules, and regulations to follow by the citizens. People have different religions and beliefs, with festivals or events that demand holidays to organize and celebrate. This criterion is related to personality dimensions (HASSAN *et al.*, 2019).	5 (8%)
C125	Updated requirements	The requirements are timely updated owing to the evolving needs of customers, stakeholders, the organization, and the work environment. Furthermore, the updated requirements show customer satisfaction, achievement of business goals, and competence in the market (AKBAR *et al.*, 2020b).	6 (9%)
C126	Change impact analysis in all sites	The impact analysis of a specific change request is important to estimate its effect on cost, time, and the system's quality. The poor analysis of the scope of demanded changes could cause the poor estimation of time, cost, and effort that could bring the project towards failure (AKBAR *et al.*, 2020b; AKBAR *et al.*, 2020a).	3 (5%)
C127	Management support	The involvement of top and lower-level management is essential to implement the Requirements change management process successfully. Besides, the participation and commitment of the management could be helpful for requirement elicitation, and change management (AKBAR *et al.*, 2020b).	3 (5%)
C128	Globally compete to market	Global competition becomes a form of international competition in which the position of an enterprise in one country affects its competitive position in other countries. As a result, companies compete for international leadership (RUN; KARMINA, 2021).	2 (3%)
C129	Progress measure in distributed sites	The amount of working software produced determines progress in agile development. In addition, source code versioning, unit testing, continuous integration, and acceptance testing are technical factors that affect the software artifacts' maturity (ALYAHYA *et al.*, 2011).	4 (6%)
C130	Management commitment	Lack of management commitment. It may be inconvenient to develop a team across the organizational border, especially when there is a possible conflict of concern or distrust. It is sometimes challenging to combine separate, independent groups into one coherent team. Management activities are not adequately performed across the boundaries due to a lack of collaboration and communication (AMMAD *et al.*, 2019; KHAN *et al.*, 2019).	4 (6%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.11 – Criteria list for contracting professionals in GSD - 5/10

Code	Criteria	Description	Cited*
C131	Software Process improvement - Consultancy	The consultancy in software process improvement is the capability of the consultants, based on their experience, to help small and medium Web companies adopt formal software process improvement standards while remaining aligned with the Web company's vision (SULAYMAN *et al.*, 2012).	2 (3%)
C132	Process improvement evaluation	Most process improvement evaluation strategies are generic, and different organizations apply those methods for measuring success indicators based on organizational needs and contexts, indicating a shortcoming in the methods used and supporting the demand for a comprehensive measurement framework (UNTERKALMSTEINER *et al.*, 2011).	2 (3%)
C133	Process improvement standards and procedures	Process improvement standards and procedures: a set of policies and standard procedures describing how the firm's processes will be conducted and maintained consistently (ATASEVEN *et al.*, 2013).	2 (3%)
C134	Site characteristics	Site characteristics, including analyst capability, programmer capability, language and tool experience, personnel continuity, and customer proximity, are variable factors in the task allocation decision (IMTIAZ; IKRAM, 2017).	1 (2%)
C135	Task site dependency	Task-site dependencies, including application experience and platform experience, are also considered during task allocation and team division (IMTIAZ; IKRAM, 2017; LAI *et al.*, 2020).	2 (3%)
C136	Personal availability	Practitioners sometimes require support to have personal availability. For example, unsurprisingly, the need for a designated professional to work with user experience is a difficulty most often pointed out by respondents from start-ups that do not have user experience professionals (SMITE *et al.*, 2021).	1 (2%)
C137	Process ownership	Process ownership is defined as placing ownership with those closest to the process who experience bottlenecks and inefficiencies. Process owners are responsible for getting the work done by workers, designing it, and ensuring the execution and high performance of the process in different organizational units (IMTIAZ; IKRAM, 2017).	3 (5%)
C138	Component dependency	Component dependencies in a product architecture give rise to communication and coordination needs. The architectural mechanisms other than module or component dependencies also create coordination requirements. The component dependencies must be addressed before allocating to temporally distant sites can be taken (IMTIAZ; IKRAM, 2017).	1 (2%)
C139	Workload	Distribution of tasks refers to the number of responsibilities distributed among the team members working at remote sites. As teams are distributed geographically and the communication among the distributed teams is less, tasks and responsibilities are not appropriately allocated. That may lead to a lack of shared understanding and confusion among the team members (AMMAD *et al.*, 2019).	4 (6%)
C140	Task Size	First, when creating tasks for user stories at the beginning of each iteration, limit the size of the tasks to 4 hours, 8 hours, or no more than 16 hours in length. Thus, this will ensure that the team can work more efficiently in a fully integrated way (**??**).	1 (2%)
C141	Participation and support to solve issues	This category consists of ideas to increase the acceptance of, and commitment to, both the organization and the transformation process. This can be achieved by the employee's participation in organizational processes and structures. Personal attachment and support towards the project Team members' ability to assist in solving problems (GOPAL *et al.*, 2018; KLUGE *et al.*, 2020b).	5 (8%)
C142	Persistent, conscientious responsiveness information of teams	The managerial practice of persistent, conscientious responsiveness information of teams on project outcomes establish pertinent information towards the project outcome (GOPAL *et al.*, 2018).	2 (3%)
C143	Project requirements	Clear software requirements are compulsory for the quality product and it changes till the completion of software development and that gradual changes create new challenges to deal with. In global software development projects, especially during knowledge transfer from provider to recipients, understanding of requirements specification is a major challenge. The vendor does not understand the designed specification properly due to a high-level design of system requirement specification (HASSAN *et al.*, 2019; NIDHRA *et al.*, 2013).	5 (8%)
C144	Capacity to absorb technical and business knowledge	Absorptive capacity is the dynamic capacity that allows firms to create value and gain and sustain a competitive advantage by managing external knowledge (CAMISÓN; FORÉS, 2010).	1 (2%)
C145	Understanding the process	Understanding the process concerning knowledge transfer effectiveness on project outcome, also to ensure process improvement a common understanding of procedures should be established, process adherence should be ensured and regular process audits should be conducted in all distributed sites (BHATTI; AHSAN, 2016; GOPAL *et al.*, 2018).	5 (8%)
C146	Mutual coordination among team members (managerial practices)	Mutual coordination among team members is the interactions and relationships among participants that have become increasingly crucial for coordinating work and improving performance. So also a mutually reinforcing process of interaction between communication and relationships carried out for task integration (RUNDALL *et al.*, 2016).	3 (5%)
C147	Clear objective	In the context of service leadership, it is necessary to have a clear objective to initiate the project in the global software development environment (SANGAIAH *et al.*, 2015b).	1 (2%)
C148	Knowledge incentive toward client business process	Knowledge-intensive business services, such as engineering, management consulting, and R&D, almost exclusively transfer knowledge and skills to client organizations—the incentives to expend effort and produce innovative services (LEIPONEN, 2006).	3 (5%)
C149	Pilot knowledge between teams	Pilot knowledge between teams is like a Café event, a space/place where we meet with friends to chat, visit and share our latest news and thoughts or make connections and build relationships that offer a relatively informal and sociable way to engage participants in conversations (POLLARD *et al.*, 2015).	2 (3%)
C150	Project functionality toward client's business process	The project functionality toward the client's business process is the relationship between business and project processes is paramount for understanding project-based firms and how they sustain competitive advantage over time as they operate in multi-actor environments and based on one-off projects (GANN; SALTER, 2000).	2 (3%)
C151	Understanding over the client's business process environment	The knowledge of client language and culture. Gathering the information and experience among teams (AKBAR *et al.*, 2020a; GOPAL *et al.*, 2018).	6 (9%)
C152	Brainstorming actions for organizations	Group thinking and decision-making are suitable tools for reducing possible errors in decision-making, improving organizations' efficiency, and utilizing scientific decision-making tools, such as Brainstorming (YAZDANI; TAVAKKOLI-MOGHADDAM, 2012).	1 (2%)
C153	Flexibility among teams	Adaptability are essential to organizational success due to environmental change. Through team working, organizations can flexibly adapt and react to turbulent, complex, and dynamic environments and thereby focus their efforts on more efficiently handling subtasks resulting in overall organizational effectiveness (ANDRÉS *et al.*, 2015).	2 (3%)
C154	Learning of innovative technology	Learning of innovative technology is the participation, acceptance, and learning incentive of innovative technology in the global service climate (GOPAL *et al.*, 2018).	4 (6%)
C155	Component or Unit Testing prior to integration	If the distributed teams submit their developed components to the central team without proper component or unit tests, the integration phase will reveal many problems delaying the whole development process, and fixing one problem may introduce another problem (ILYAS; KHAN, 2015).	2 (3%)
C156	Advance and Uniform Development Environment and Training	For the Advance and Uniform Development Environment, all the development teams in GSD must use the same development environment. Even to use the latest technology and tools, the developers need to be trained appropriately to acquire the required skill and knowledge to ease the integration process in the long run (ILYAS; KHAN, 2015).	5 (8%)
C157	Continuous integration	Continuous Integration is a software practice where developers frequently integrate, at least daily (STÅHL; BOSCH, 2013).	3 (5%)
C158	Interface Compatibility	In software development, different components in a product interact and integrate through well-defined interfaces. Through interfaces, the component avails and provides services. Therefore, the software developer should develop in-house components or select COTS components that are loosely coupled and have well-defined software interfaces to fit into the final product easily (ILYAS; KHAN, 2015).	1 (2%)
C159	Configuration management	In configuration management, the component version should easily track each component from start to final delivery. A different version of a product may have different sets and different versions of components, which need to be managed consistently and adequately for successful product integration (ILYAS; KHAN, 2015).	3 (5%)
C160	Components evaluation	Almost all types and sizes of software are composed of more than one software component or module developed in-house or outsourced. Similarly, in components evaluation, the components may be purchased from the market as a commercial off-the-shelf (COTS) component or from the large pole of the open-source community as an off-the-shelf (OTS) component (ILYAS; KHAN, 2016).	1 (2%)
C161	Process, Data and Product's Components	Typically, during the design process, the design team must identify adequate components to fulfill specific design requirements and use a standard model for process, data, and product components (COSTA; MADRAZO, 2015).	3 (5%)
C162	Metrics	Automated metrics allow for to definition of code complexity metrics. Semi-automated metrics allow us to measure functional complexity, for example. Finally, manual metrics allow the frequency of use and the importance for the user (BASTIDAS *et al.*, 2021).	4 (6%)
C163	Specific Integration Timing	The specific integration timing in the integration phase, or the synchronizing of the various parts, is one of the most challenging phases of software projects in the GSD environment (ILYAS; KHAN, 2016).	1 (2%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.12 – Criteria list for contracting professionals in GSD - 6/10

Code	Criteria	Description	Cited*
C164	Organization: resource	The resource-based view of the firm indicates that the activities in which an enterprise engages consist of a bundle of resources which include assets, processes, attributes, knowledge, information, and know-how that a firm possesses and can therefore use to formulate and implement competitive strategies (COATES; MCDERMOTT, 2002).	1 (2%)
C165	Organization: strategies	Due to economic expansion, the sophistication of communication means, and cost pressure, it is crucial to comprehend the risks, challenges, opportunities, and good practices within this new software development scenario to construct business strategies (MARQUES *et al.*, 2012).	1 (2%)
C166	Organization: standard	Standard in an organization is a behavioral approach like style (textual, formal); the organizational and operational environment; organization condition; usage context; knowledge type; requirement purpose; organization customs; type of product; and development process (JACKSON; SCHULER, 1995).	1 (2%)
C167	Organization: culture	The organizational culture encompasses the employees' values, beliefs, and behaviors. Values, beliefs, and behaviors become assimilated into an organizational ideology or philosophy, which serves as a guide for dealing with the uncertainty of uncontrollable or difficult events that occur in organizational life (ROSCOE *et al.*, 2019).	5 (8%)
C168	Organization: politics	Organizational Policy is mainly expressed as a particular behavior of a person, which includes intentional actions to effect specific decisions to safeguard their interests (YASMEEN *et al.*, 2019).	1 (2%)
C169	Organization: practices	Organizational Practices are the behaviors and actions of employees. Hence, are the employees' daily work habits aligned with the core values of organizational culture? Practices are one of the Five Ps (purpose, philosophy, priorities, practices, and projections) of an organization (MARGOLIS, 2022).	1 (2%)
C170	Organization: regulations	The regulation describes any attempt to influence a population's behavior, whether by law, force, nudging, or surreptitious manipulation (HILDEBRANDT, 2018).	1 (2%)
C171	Organization: environment	The internal environment aspect can be observed using a functional approach consisting of production and operations, human resources, finance, management, and marketing information systems. The external environment is all circumstances outside the organization that has the potential to influence the organization (MULYANI *et al.*, 2020).	1 (2%)
C172	Organization: structure	The organizational structure that has proven effective in practice is characterized by a flatter structure, decentralized decision-making, greater collaboration and coordination, faster knowledge transfer between employees, knowledge networking, teamwork, proactive approach, horizontal communication, flexibility, and agility (MIRKOVIĆ *et al.*, 2019).	2 (3%)
C173	Organization: size	The organizational size is defined as the number of employees at any given location, and this would include the entire corporate organization if it is in one geographical location or a division of a decentralized corporation (BEER, 1964).	1 (2%)
C174	Inter-team culture (NCASN)	Inter-team culture is related to National Culture and Social Norms (GULZAR *et al.*, 2018).	1 (2%)
C175	Social facilities	Inequality manifests in the unequal provision of social amenities within local government districts. The social amenities are educational, health, and market facilities, like drinking water, sanitation, electricity, housing qualities, and drainage arrangement. It is connected to geographic dimension (GULZAR *et al.*, 2018).	1 (2%)
C176	Social interaction	Social interaction is how individuals act and react concerning one another (CERULO, 2009).	2 (3%)
C177	Stakeholder: Client	The person paying the bill or the initial paying customer can be seen to be the project client (WALKER, 2000).	2 (3%)
C178	Stakeholder: Relationship	The stakeholder relationship is associated with customer feedback to improve development (RAFI *et al.*, 2022).	3 (5%)
C179	Stakeholder engagement	Stakeholder involvement is essential for successful project delivery and is often considered a boundary activity or one that can be outsourced to business functions as usual. Nonetheless, project managers depend on people to respond to the outputs and benefits they deliver, and people will only respond if they are engaged (MACNICOL *et al.*, 2014).	3 (5%)
C180	Stakeholder: requirements	Stakeholder Requirements, or user requirements, describe what users do with the system, such as the activities that users must be able to perform. Usually, we use narrative text, use cases, scenarios, user stories, or event-response tables to document it (**??**).	2 (3%)
C181	Stakeholder Performance Domain	This domain addresses activities (identifying, analyzing, prioritizing, engaging, and monitoring)and functions associated with stakeholders (PMI, 2021).	1 (2%)
C182	Stakeholder: problem domain	Pushing knowledge beyond the constraints of the previous domain into new fields means that the boundaries of a theory receive more testing and support. Furthermore, these advances mean a greater understanding of when a theory works and why. Thus, the problem and solution domains are considered more mature (GREGOR; HEVNER, 2013).	2 (3%)
C183	Stakeholder Attitude	In varying degrees, attitudes comprise three components, known to behavioral phycologists as the ABC Model of Attitudes Saul McLeod. A: effectively based attitudes are the emotional reactions we have to an Attitude Object. B: behavioral attitudes express themselves when we react to an Attitude Object. C: cognitive attitudes are rooted in our beliefs about the Attitude Object (FISCAL, 2018).	1 (2%)
C184	Climatic condition	Weather generally refers to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over more extended periods. Climate is the average weather conditions for a particular geographical location over notable years (KRISHNAMURTHI *et al.*, 2015).	2 (3%)
C185	Geological condition	Ecological-geological conditions are considered a geographical environment created by a set of contemporary morphologically expressed geological factors that influence specific features of the functioning of the biota, including human beings, within the framework of the ecological-geological system (TROFIMOV, 2010).	1 (2%)
C186	Working and workplace atmosphere	Temperature, air quality, lighting, and noise in the office affect work concentration and productivity. Numerous studies have consistently demonstrated that the physical office environment's characteristics can significantly affect employees' behavior, perceptions, and productivity (KAMARULZAMAN *et al.*, 2011).	1 (2%)
C187	Project: Characteristics	The main characteristics of the project are defined by: the way the work groups are organized, the project manager's level of authority; the level of dedication of the project manager; the availability of resources; who manages the budget; level of dedication of project management administrative staff (PMI, 2021).	1 (2%)
C188	Requirement estimation	An estimate predicts how long a project will take or how much it will cost. Estimation and planning are related topics, but estimation is not planning, and planning is not estimation. Therefore, estimation should be treated as an unbiased, analytical process, and planning should be treated as a tiny, goal-seeking process (POPLI; CHAUHAN, 2012).	1 (2%)
C189	Collaboration, communication and coordination: inter-team, inter-site	Internal project communication, intrainformation, and interinformation sharing across distributed sites. Requirements change management is considered a rich communication activity in GSD and an efficient information-sharing mechanism that facilitates the information management, integration, and coordination of Requirements change management activities across distributed sites (KHAN; AKBAR, 2020; AKBAR *et al.*, 2020a).	10 (15%)
C190	Collaboration, communication and coordination: cross-boundary	The requirement change management is considered to be a rich communication activity, and an efficient information sharing mechanism that facilitates the management of the information, integration, and coordination of the activities across distributed sites has a significant positive impact in the GSD environment (KHAN; AKBAR, 2020).	7 (11%)
C191	Tools and technology: process selection	Whenever there is a significant time difference between remote team videoconferencing and any communication technology such as Skype is not suitable, in this case, email is the most recommended technology for communication between team members. Team members get instant feedback with chat, but the richness of tonal expression gained from voice calls has been lost (AMMAD *et al.*, 2019).	3 (5%)
C192	Project management performance	Project management performance questions: extent and frequency of plan changes; frequency of emergency meetings; agreement between effort invested and effort required; participant satisfaction; customer satisfaction; the number of post-delivery product changes (RAZ; MICHAEL, 2001).	2 (3%)
C193	Tools and technology: management decision	Technology management tools are a subset of management tools related to decision-making and support around innovation-related activities in strategic decision-making about which technologies to invest in: R&D project selection, new product selection, capturing customers' needs, designing new products, promoting creativity, and monitoring and controlling development projects (BRADY *et al.*, 1997).	2 (3%)
C194	Tools and technology: defect occurrence	Defect data contain knowledge about specific work conditions. A data feedback mechanism is required to prevent the reoccurrence of defects. However, most defective data are stored in unstructured ways, resulting in the fundamental problem of data utilization (LEE *et al.*, 2016).	1 (2%)
C195	Tools and technology: testing accuracy	A project's success or failure depends on the accuracy and effective management of requirements. Therefore, it is crucial to determine the mix of practical techniques for requirement acquisition and adequately document the process and the requirements to reduce the challenges and chances of failure (HUSSAIN *et al.*, 2016).	2 (3%)
C196	Knowledge assets	The widespread use of the terms in the following list hint at the increased importance knowledge assets have in organizations: intellectual capital, knowledge capital, knowledge organizations, learning organizations, organizational learning, information age, knowledge era, information assets, intangible assets, intangible management, hidden value, and human capital (BONTIS, 2001).	1 (2%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.13 – Criteria list for contracting professionals in GSD - 7/10

Code	Criteria	Description	Cited*
C197	Trust: among team members	Trust among team members is the confidence of development team members (LAI *et al.*, 2020).	3 (5%)
C198	Trust: cross-boundary	Trust building is a critical factor for developing cross-boundary information sharing and, in a much broader sense, is a crucial element of the social capital needed for any successful cooperation or collaboration within and across social networks (PARDO *et al.*, 2008).	1 (2%)
C199	Trust: confidence in the company and leadership and other stakeholders	The mere act of mingling with employees promotes the concept of the leader as just another colleague. During that interaction, if employees feel confident expressing a personal concern or need, presumably due to preexisting trust, the leader should act on that to further reinforce trust and demonstrate care and respect. If the leader acts reasonably, trust and confidence in the leader will increase (GORDON; GILLEY, 2012).	2 (3%)
C200	Team size/ structure	Team size refers to the number of people working together as a team to achieve certain goals. Team size is a major factor in a software development project. In general, there are three different team sizes, i.e. small team consisting of a maximum of ten members for a small project, medium size team consist of members ranging from 11 to 25, and a large team involving at least 26 members, an appropriate for a large project (AMMAD *et al.*, 2019).	9 (14%)
C201	Team cohesion	Team spirit is the satisfaction and honesty that coexists between the team members and motivates them to do well or be the best. Unfortunately, in Global software development, teams are geographically dispersed, which may decrease the opportunity for effective communication and acquiring the benefits of a collocated environment and may lead to the loss of team cohesion and project failure (AMMAD *et al.*, 2019).	4 (6%)
C202	Capability to adopt team members	The project manager should adopt other team members to the project, increase the project's coordination and integration among project elements and use a consistent method to guide and control project execution (BAKAR *et al.*, 2011).	1 (2%)
C203	Team experience	The team experience evolves different project background issues arise due to the difference in working culture when developers from different countries need to work on a project that is not similar to the existing project background (AMMAD *et al.*, 2019).	5 (8%)
C204	Requirement management	Monitoring and controlling the requirements change management activities at offshore sites (AKBAR *et al.*, 2020a).	5 (8%)
C205	Global project management issues	Requirements engineering meetings needs: engaging a human facilitator and using rich communication media that supports data, videos, and audio integration; preparing agenda and following it; selecting relevant participants and informing them of times to participate in requirement meetings; timely exchanging supporting documents to give participants enough time to read the relevant material; enabling participants of requirements meetings to access the resources that contain information about the requirements (IQBAL *et al.*, 2022).	4 (6%)
C206	Face to face meeting	In general, due to the geographical dispersion among sites, limited face-to-face meetings can decrease the opportunity for informal interaction, leading to a lack of team awareness and cohesiveness. Also, misunderstanding requirements are probably due to a lack of interaction (RAFI *et al.*, 2022; AMMAD *et al.*, 2019).	6 (9%)
C207	User involvement	Involving end users during system development is paramount to ensuring project success. User involvement in development has many benefits: it delivers a more accurate and complete assessment of user requirements, provides the developers with knowledge of the information system's organizational and functional context, and increases users' acceptance of the new system (RAFI *et al.*, 2022; AMMAD *et al.*, 2019).	2 (3%)
C208	Labor cost	Labor cost is the leading reason organizations go global, but the availability of human resources is more important than cost. Large Global Software Development organizations try to find available human resources in their regional offices, whereas others find the available skill set by outsourcing. Today's global market is about where resources are available. It is a human resource dimension (**??**).	2 (3%)
C209	Human related problems	Companies' common human resource problems are compliance with laws and regulations, health and safety, change management, compensation management, landing top talent, retention, and monitoring productivity and performance (MCCONNELL, 2021).	1 (2%)
C210	Technical Infrastructure	Technical incompatibilities among distributed sites cause communication obstacles due to technological issues. A project having various distributed teams introduces the probability of an incompatible database that may cause a threat of loss of data when transferring from one database to another. Distributed team members use different programming languages, which may cause conflict on the preferred technology or delay in communication as a result of incompatibilities of the artifact (AMMAD *et al.*, 2019).	6 (9%)
C211	Infrastructure	Potential differences in infrastructure across sites might lead to compatibility issues. Therefore, the GSD sites need to adopt advanced and uniform infrastructure while executing the requirement change management process (AKBAR *et al.*, 2022).	3 (5%)
C212	Effort and cost estimation for change	Software changes are inevitable due to the dynamic nature of the software development project itself. One factor influencing the effectiveness of the change acceptance decision is the accuracy of the change effort estimation (BASRI *et al.*, 2016).	1 (2%)
C213	Productivity	The primary ingredients that impact the software development productivity of globally distributed projects are project delivery rate, team size, and communication complexity. The project distribution can be effectively done depending on the estimated productivity of the different sites (RAY; SAMUEL, 2016).	1 (2%)
C214	Project methodology (approach, mentoring)	Nowadays, the rise and fall of software companies are standard. Those who learned lessons from their past failures succeeded. Due to advances in technology, new approaches and methods are under development. The software industry also adopts new approaches with changing technology and techniques (HAYAT *et al.*, 2019).	4 (6%)
C215	Quality of build	Build quality comprises the risk variables, requirements analysis, design, and construction. Therefore, the project manager must be diligent in formulating and adopting appropriate quality processes, procedures, tools, templates, techniques, guidelines, and standards (SUNDARARAJAN *et al.*, 2019).	1 (2%)
C216	Quality of test	Test quality underlies the risk variables, adaptation, regression, and performance tests. A regression test ensures that software changes do not break functionality. Performance tests are performed to ensure that software changes do not affect application performance. A retrofit test is about incorporating changes already made to production code in parallel by other project teams (SUNDARARAJAN *et al.*, 2019).	1 (2%)
C217	Team rewards and recognitions	Human resource practices should be selected that complement and support an organizational strategy. More specifically, the human resource reward system should be aligned to motivate employee performance that is consistent with the firm's strategy, attract and retain people with the knowledge, skills, and abilities required to realize the firm's strategic goals and create a supportive culture and structure. It is a human resource dimension (ALLEN; HELMS, 2002).	1 (2%)
C218	Employee facilitation	Employee facilitation includes individual initiatives, mentoring by a core team, and employee work-life balance. Also, work-life balance and the need for attractive packages for hiring (HUSSAIN *et al.*, 2021; SUNDARARAJAN *et al.*, 2019)	3 (5%)
C219	Alignment between architectural decisions to organization structure	Lack of alignment between architectural decisions to organization structure and not reflecting architectural changes to an organization; challenges brought by misalignment between organization and architecture; challenges brought by personnel changes; difficulties ensuring compliance of modular design throughout the lifecycle and changes in an organization (AMMAD *et al.*, 2019; **??**).	2 (3%)
C220	Project instability	Project instability manifests itself as changing team structures, responsibilities between sites, personnel changes, and roles of existing personnel (SIEVI-KORTE *et al.*, 2019).	2 (3%)
C221	Software quality control	The software quality control comprises: delegating design decisions to the local team, deteriorating quality; poor quality management; decentralized data and state management leading to inferior quality; insufficient automation for testing and a lot of manual tests; insufficient recording of quality requirements (SIEVI-KORTE *et al.*, 2019).	3 (5%)
C222	Align architecture with organization arrangement	Align architecture with organization arrangement, include business goals in design, base architectural decisions on available resources, and establish quality management practices (SIEVI-KORTE *et al.*, 2019).	2 (3%)
C223	knowledge management practices	Insufficient knowledge management practices between projects and across the organization. Disagreement in design choices. Problems recognizing and caused by conflicting assumptions on software. Insufficient understanding of architectural decisions in teams and other stakeholder groups. Incorrect assumptions made during design. Unclear ownership of architectural elements (SIEVI-KORTE *et al.*, 2019).	3 (5%)
C224	Communicate architectural decisions to all stakeholders	Establish practices enhancing communication and knowledge distribution. Architects should handle communication with different stakeholders, considering stakeholders' backgrounds. Communicate architectural artifacts and practices clearly to all sites. Maintain a single repository for architectural artifacts accessible to all (SIEVI-KORTE *et al.*, 2019).	1 (2%)
C225	Conformance to share practices	Conformance to share practices is the ignorance of or incorrect use of principles, rules, and guidelines for architectural design and knowledge management. Lack of stability in architecture leads to difficulties in applying design rules and dividing tasks. Inconsistent versioning. Insufficient interface specifications (SIEVI-KORTE *et al.*, 2019).	2 (3%)
C226	Standardize architectural practices	The standardized architectural practices ensure that teams develop code based on standard design agreements. Thus, use common architectural practices and ensure they are well-defined, consider a service-oriented approach, take advantage of Agile methods, use prototyping, and ensure fit to requirements (SIEVI-KORTE *et al.*, 2019).	1 (2%)
C227	Identifying dependencies on architectural design decision	Identifying dependencies on architectural design decisions, insufficient decoupling, or cross-component features are challenges brought about by software complexity and difficulties defining logical entities and finding interface boundaries in architecture (SIEVI-KORTE *et al.*, 2019).	2 (3%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.14 – Criteria list for contracting professionals in GSD - 8/10

Code	Criteria	Description	Cited*
C228	Architectural design practices	Architectural design practices are about implementing well-defined interfaces to increase modularization and aid loose coupling. Strive for high modularity and separation of concerns. Locate dependencies within architecture (SIEVI-KORTE *et al.*, 2019).	1 (2%)
C229	Architecting modeling techniques	Architecting modeling techniques use (call) graphs/matrices to depict and detect coupling. Use visualization of decisions/metrics. Use collaborative modeling. Using a variety of diagrams promotes awareness (SIEVI-KORTE *et al.*, 2019).	1 (2%)
C230	Task allocation	Allocation of the core team. Allocation of a whole team. An increased amount of effort with modifications involving several developers across different sites. Increased needs for coordination when using experts from different sites. Difficulties evaluating work input due to distribution. Difficulties in synchronizing tasks. Insufficient matching of code to available resources. Difficulties with correctly identifying dependencies between work units and thus assigning work to distributed teams. Insufficient prioritization rules (SIEVI-KORTE *et al.*, 2019; SUNDARARAJAN *et al.*, 2019; KHAN; AKBAR, 2020).	4 (6%)
C231	Architecture-based task allocation	Architecture-based task allocation identifies where the domain expertise lies and allocates tasks accordingly. Retain tightly coupled work items at one site. Acquire and arrange resources based on architecture. Base work allocation on available resources and minimize the need for communication between sites (SIEVI-KORTE *et al.*, 2019).	2 (3%)
C232	Compliance to processes	Challenges due to inconsistent standardization, tools, and equipment between sites. The schedule is prioritized over processes. Challenges fitting practical work to defined processes. Problems caused due to not involving a technical architect. Impractical condensing of knowledge due to high dependency on one lead architect (SIEVI-KORTE *et al.*, 2019; SUNDARARAJAN *et al.*, 2019).	6 (9%)
C233	Governance implemented	This criterion contains one concern that encourages engaging developers across sites. Assign responsibilities for prioritization, managing architectural work, and sharing knowledge with teams. Break work items into easily manageable pieces (consider one subsystem, can be handled by one person). Define clear responsibilities for the architecture team to handle changes spanning several components and/or sites. Ensure each site has a representative architect. Engage developers across sites in architectural work (SIEVI-KORTE *et al.*, 2019).	4 (6%)
C234	Handling soft issues	Handling soft issues requires more commitment to software development processes and guidelines and more commitment or interest in work items (distributed across sites) by individuals. It is a behavioral characteristic comprised of misaligned interests, lack of report progress, and tasks' undesirability, making task distribution challenges. It is related to personality dimensions (SIEVI-KORTE *et al.*, 2019).	1 (2%)
C235	Socio-culture distance	Every culture has its standards, styles, and moral principles that can provoke communication-related issues. Socio-cultural distance includes national, organizational, political, and religious background and moral values, which increases the probability of misunderstanding, which may negatively impact the team's performance (AMMAD *et al.*, 2019).	2 (3%)
C236	Team member's attitude	Team members' attitudes express the satisfaction or dissatisfaction towards an individual, working environment, or event and an individual's behavior. The impact of attitudes influences communication in optimistic and pessimistic ways because of the individual's religious belief, personal attitudes, mindset, and knowledge (AMMAD *et al.*, 2019).	1 (2%)
C237	Customer relationship	The customer may be far from the development team, and it is difficult for them to travel to elaborate on the requirements in detail. Customers usually show little involvement while discussing the requirements in detail during the development process, which may lead to a weak relationship between the developer and the customer (AMMAD *et al.*, 2019).	5 (8%)
C238	Cost and logistics of meetings	In GSD, sometimes it is essential to conduct face-to-face meetings, mainly in the initial phases of the project. However, it can be very costly and time-taking to travel frequently to a remote location. Moreover, logistical issues such as visa insurance, flight connectivity, and traveling charges also contribute to the problems caused by geographical distance among remote sites (AMMAD *et al.*, 2019).	1 (2%)
C239	Effort to initiate contact	The effort to initiate contact is an obstacle between team members isolated by geographic distance. In addition, it may lead developers to make a minor modification to the system without contacting someone with rich knowledge about it (AMMAD *et al.*, 2019).	1 (2%)
C240	Time overlapping	Less overlapping working hours increase the possibility of using asynchrony communication, as the overlapping working hours is the only time synchrony communication is feasible (AMMAD *et al.*, 2019).	2 (3%)
C241	Communication frequency	The communication frequency decreases in a remote location due to temporal distances. In addition, critical concerns may be reported after a period, which could affect work patterns and schedules for the next business day. Due to the low frequency of communication between distributed teams, the risk of communication failures and misunderstandings increases (**??**).	5 (8%)
C242	Detailed level of communication	Due to the low communication frequency among distributed teams, the risk of miscommunication and misconception increases, provoking a low detailed level of communication (**??**).	2 (3%)
C243	Mutual understanding	In interdisciplinary requirements engineering, stakeholders need to understand how other disciplines think and work (mutual understanding) and agree on the system they develop (shared understanding) to collaborate effectively (HOFFMANN *et al.*, 2013).	1 (2%)
C244	Domain of manager's opinion	The attitude of the manager or team leader, which has to diverge points of view and opinions, influence the effective communication between the team members attitude. Also, restricting all forms of interaction and communication between the distributed teams working in GSD may lead to miscommunication, and misunderstanding (AMMAD *et al.*, 2019).	1 (2%)
C245	Connectivity issues	Since virtual teams rely on electronic communication, any internet downtime could isolate team members and halt workflow. In addition, such technologies as web conferencing, instant messaging, document-sharing sites, and the like can supply rich communication conditions for team members who cannot hold face-to-face encounters (AMMAD *et al.*, 2019; AKBAR *et al.*, 2020a).	2 (3%)
C246	Degree of infrastructure	Countries with limited infrastructure limit rich discussions between team members, which can influence the transmission of informal news or casual conversations during informal meetings. Failures of these limited infrastructures of communication technologies can result in poor interaction, and communication (AMMAD *et al.*, 2019; AKBAR *et al.*, 2020a).	6 (9%)
C247	Quality of telecommunication bandwidth	The low quality of telecommunication bandwidth is a communication issue because the context, tone, and emotion could be disoriented. This problem leads to an excess of time describing things being addressed, and with poor transmission quality hampering communication implements, communication networks can be slow and unreliable (AMMAD *et al.*, 2019).	1 (2%)
C248	Lack of ICT and technological cohesion	We need technology that creates shared understanding. We need people who understand how to build bridges in divided communities to be better equipped to use technology, avoiding deficiencies in the current digital environment (BJÖRKDAHL; KRONBLAD, 2021).	4 (6%)
C249	Uniform processes	Lack of uniform process between different development sites. Best practices are: to organize process-based training for new employees; ensure that management-level workshops synchronize global processes; follow standard processes and tools; follow a single process with all teams; follow documentation standards; adopt process evaluation standards, and establish process training programs in the organization (NIAZI *et al.*, 2020).	2 (3%)
C250	Communication of customer requirements	Communication of customer requirements allows for identifying the user's requirements and relevant derivative acceptance criteria to establish test priorities. Failures to meet customer requirements and expectations are often related to misunderstanding and misconception (UNTERKALMSTEINER, 2015; BASTIDAS *et al.*, 2021; AMMAD *et al.*, 2019).	2 (3%)
C251	knowledge creation ability among the teams	The multiplicity of different actors with different expertise sets makes it challenging to understand each other in virtual teams. This shared understanding is the set of norms, behaviors, and understanding team members have about the assumptions, tasks, work processes, and contexts necessary for effective and successful collaboration (MALHOTRA; MAJCHRZAK, 2004).	3 (5%)
C252	Ability to solve their professional problems	The individual with a clear vision to solve their professional problems toward the project result. The extent to which the customer leader took the individual initiative and shared responsibility for developing solutions and resolving issues and problems that arise in the team relationship. The developer or a person proactively identifies and resolves potential problems with the proposed solution. It is related to personal technical dimension (BETTENCOURT *et al.*, 2002).	1 (2%)
C253	Cooperation and competition within the teams' to fulfill the goals	The organization's needs are best served by employing cooperative reward structures. Collaborative systems incorporate norms of equality and emphasize group accomplishments. They emphasize downplaying distinctions among group members (i.e., performance-based distinctions) because they can inhibit teamwork, information sharing, and helping (BEERSMA *et al.*, 2003).	2 (3%)
C254	Explicit and standard communication pattern for knowledge transfer effectiveness	To facilitate the interpretation and integration of the knowledge transfer process, we must create norms providing a standard frame of reference and definitions of key technical terms. Thus, shared knowledge influences the efficiency of this process by facilitating the transfer of knowledge (BLUMENBERG *et al.*, 2009).	2 (3%)
C255	Specialty ability of the teams	The gap in the teams' specialty ability would lead to some differences in performance. The practitioners with lower specialties might need more solid knowledge foundations (hard skills) and are comparatively weaker in thinking and learning abilities. Their self-confidence, motivation, and soft skills are insufficient (CHEN *et al.*, 2011).	1 (2%)
C256	Mediating role knowledge transfer	Strong ties effectively provide valuable knowledge. Such relationships are helpful because they tend to be trusting. The benevolence and competence-based trust mediate the link between strong ties and the receipt of helpful knowledge (LEVIN; CROSS, 2004).	1 (2%)
C257	Assessment of teams knowledge transfer effectiveness	The assessment on knowledge transfer methods for development teams are documentation, mutual code reviews, code comments, pair programming, face-to-face question and answer sessions, mentoring, hackathons, brown bag lunches (BBLs), writing tests, communication and collaboration tools, and communities of practice (DZIUBA, 2021).	2 (3%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.15 – Criteria list for contracting professionals in GSD - 9/10

Code	Criteria	Description	Cited*
C258	Communality	Communality refers to the personal characteristics that the trustor has in common with the trustee, like a similar goal they wish to achieve, shared language use, common identity characteristics, or shared values. It is a personal technical dimension (VIZCAÍNO *et al.*, 2018).	1 (2%)
C259	Benevolence	Benevolence is the willingness to help, availability, sharing, faith in intentions, friendliness, openness, caring, and commitment. Also, it refers to the perceived level of courtesy and positive attitude a trustee displays towards the trustor (VIZCAÍNO *et al.*, 2018).	1 (2%)
C260	Internalised norms	Internalized norms are integrity, discretion, honesty, fairness, and loyalty. This criterion refers to the intrinsic moral norms a trustee uses to guard his/her actions. The language Analysis regarding how a trustee uses the chat and walls could infer some people's values (VIZCAÍNO *et al.*, 2018).	1 (2%)
C261	Accountability	Accountability refers to the degree to which a person is liable and accountable for his/her acts and meets another person's expectations. It includes the extent to which a person seems to be: reliable, consistent, self-confident, persistent, and responsible (VIZCAÍNO *et al.*, 2018).	1 (2%)
C262	Interpersonal relationships skills	In GSD, communication becomes low due to a lack of group interaction among distributed team members, which initiates multiple communication issues. Lack of interpersonal relationships originates due to geographical distance among globally distributed teams. Therefore, due to improper communication at remote sites, task dispute occurs, which might lead to relationship conflict and the frequency of rework increases (AMMAD *et al.*, 2019).	3 (5%)
C263	Reasoning skills	The ability to reason with emotions, or emotional reasoning skills, is the ability to employ emotional knowledge to understand and analyze emotions. Specifically, it includes capabilities such as understanding the links between emotion-eliciting situations and emotional reactions and describing one's and others' emotional experiences (VIZCAÍNO *et al.*, 2018).	2 (3%)
C264	Communication protocols and customs	A communication Protocol is a system of rules that allows two or more entities in a communications system to transmit information via any variation of a physical quantity. Communication protocols are formal descriptions of formats and rules for producing digital messages for electronic data exchange (YEROMIN, 2020).	1 (2%)
C265	Communication skills in a second language	There are four language and communication skills: listening, speaking, reading, and writing. These four language skills allow an individual to comprehend and produce spoken language for proper and effective interpersonal communication. Skills can be oral or written and active or passive (GALACZI, 2018).	3 (5%)
C266	Ability to motivate others and create trust	The ability to motivate others and create trust happens when a person can motivate and inspires; builds potential in others; creates an environment that fosters learning, collaboration, and fluid teamwork, and attracts high performers (KLINGBORG *et al.*, 2006).	3 (5%)
C267	Extroversion (personality dimensions)	Extroverted behaviors, for example, tend to result in a higher frequency of communication through electronic messages and increased team performance. It was found that high levels of positive personal traits, such as helpfulness and agreeableness, increased team performance satisfaction (MONASOR *et al.*, 2012).	1 (2%)
C268	Computer anxiety (personality dimensions)	In terms of anxiety, computer anxiety is the interactions with computers, negative global attitudes, and negative cognitions or self-critical internal dialogue. It is related to personality dimensions (KORUKONDA, 2007).	1 (2%)
C269	Self-control (personality dimensions)	Self-control is the personal aptitude and behavior to do work. It is related to personality dimensions (ALI; LAI, 2021).	2 (3%)
C270	Sensitivity (personality dimensions)	Enhanced sensitivity predicts both reactivities to adverse contexts and the propensity to benefit from supportive resources from favorable environments. In other words, sensitivity is proposed to better and worse influence the impact of environmental influences (ASSARY *et al.*, 2021).	1 (2%)
C271	Emotional stability (personality dimensions)	Emotional stability (i.e., calm, steady, self-confident, and secure), of the five major personality dimensions, conscientiousness, and emotional stability are the most valid predictors of performance outcomes across different occupations (LOCKE, 2011).	1 (2%)
C272	Conscientiousness (personality dimensions)	Conscientiousness describes a person's ability to regulate impulse control to engage in goal-directed behaviors. It measures elements such as control, inhibition, and persistence of behavior. It is related to personality dimensions (LIM, 2020).	1 (2%)
C273	Charismatic leadership	Exceptional leaders transform followers' needs, values, preferences, desires, and aspirations from self-interests to collective interests, alternatively called charismatic, visionary, transformational, and inspirational leadership. It is claimed to influence followers in quantitatively more significant and qualitatively different ways than the follower effects specified in past leadership theories (**??**).	1 (2%)
C274	Age	Age is the number of years a person has lived. The age criteria are because cognitive functions begin to decline as the person age. Thus, older people may have more difficulty coping with managing an eventful daily routine, even those experiencing a healthy aging process. It is a personal technical dimension (MELO *et al.*, 2016).	1 (2%)
C275	Frequent information sharing	Up-to-date progress reporting, and an organized frequent meeting among distributed teams (KLUGE *et al.*, 2020b; AKBAR *et al.*, 2020a).	5 (8%)
C276	Requirements elicitation techniques	Requirements elicitation is the process of defining stakeholders' needs and putting this information together in an understandable manner such that developers can construct a system that will address those needs (ALDAVE *et al.*, 2019).	1 (2%)
C277	Client and vendor organizational management commitment	Due to change frequently occurring in requirements during the system development process, organizational management must commit to and support change management activities. Therefore, upper and lower management involvement is essential to implement the RCM process successfully (AKBAR *et al.*, 2020a).	2 (3%)
C278	Financial maturity	Financial maturity is when a stand's anticipated future value growth will not increase the firm's net worth. The comparison of the internal rate of return and present net worth solutions illustrates that the various financial maturity models may be distinguished according to implicit or explicit assumptions regarding the accessibility of factor markets on input fixities (BENTLEY; TEEGUARDEN, 2018).	2 (3%)
C279	Use of English for communication	Use of English for communication. It is recommended to do some tests to see if practitioners detect some errors in conversations in English (chats, emails, or phone calls) and show that they notice communication problems when non-native languages are being used (VIZCAÍNO *et al.*, 2019).	1 (2%)
C280	Informal communication	Lack of informal communication leads to a lack of mutual understanding of project goals, misunderstanding of requirements, and mistrust between distributed teams. In addition, a lack of informal communication between team members can result in a lack of implicit knowledge (AMMAD *et al.*, 2019).	4 (6%)
C281	Experienced staff	Experienced staff plays an essential role: a pre-start project briefing session; assigning inexperienced employees with experienced employees whenever possible; language training for long-term assignments if language is a crucial component; and briefings on payroll, pension, and tax aspects (WELCH *et al.*, 2008).	2 (3%)
C282	Agile team training	Adopting Agile-driven team training methodologies is an efficient way of excelling in agile software project management with significant advantages in production costs, time-to-market, complexity, and quality improvement over traditional human resource management methodologies. It is a human resource dimension (HUZOOREE; RAMDOO, 2015).	2 (3%)
C283	Budget constraints	The firm's retained earnings mainly determine budget constraints, the net present value of its future investments, the quality of its management, and the liquidation value of its assets are other examples (BOLTON; DEWATRIPONT, 1995).	2 (3%)
C284	Project scope	Project scope is the work that must be performed to deliver a product, service, or result with specified characteristics and functions (PMI, 2021).	2 (3%)
C285	Organizational commitments	Employees feel compelled to reciprocate when offered valuable resources via social exchange and reciprocity mechanisms. Support, as it constitutes a socioemotional resource, leads employees to experience affective commitment toward the organization. Furthermore, organizational support may contribute to an affective commitment by fulfilling basic socioemotional needs, such as affiliation, approval, and respect (PANACCIO; VANDENBERGHE, 2009).	1 (2%)
C286	Scaling tools and standards	Beyond regular global projects, agile scaling involves many challenges, including coordination among multiple agile teams and the need for an initial architecture and requirement analysis. Several frameworks for scaling agile software development have been suggested, such as the Scaled Agile Framework (SAFe), Disciplined Agile Delivery, Large-Scale Scrum, Nexus, and Scrum@Scale (MARINHO *et al.*, 2021).	1 (2%)
C287	Error management culture	The error management culture refers to the organization's culture of bargaining with errors. A productive culture of error is seen as a prerequisite for a successful digital transformation, especially during the transition phase (KLUGE *et al.*, 2020b).	1 (2%)
C288	Handling of data	Handling of data describes competence in the handling of data, also includes large data volumes and data security (KLUGE *et al.*, 2020b).	1 (2%)
C289	Lifelong learning	Lifelong learning is the individual behavior to develop competencies for performing the various roles required in human life and figuring out the learning skills by keeping the learning curve unrestricted. This process happens especially when the characteristics of the change in activity cannot be explained based on native response tendencies, maturation, or temporary states of the organism. It is a personal technical dimension (KLUGE *et al.*, 2020b).	1 (2%)
C290	Legislation and regulation with cloud provider	In July 2014, ISO and IEC published a public cloud computing and data protection standard. The standard aims to address the downsides of cloud computing and the concerns of the cloud clients, mainly the lack of trust and transparency, by developing controls and recommendations for cloud service providers acting as personally identifiable information processors (HERT *et al.*, 2016).	1 (2%)
C291	Choose the right cloud service provider	Cloud computing is risky since there is no guarantee that the information is monitored or preserved by the service provider. In addition, the transition from local computing to cloud computing has created several security issues for the client and service provider. The suggested mitigation techniques to address these threats are encryption, access control, and blockchain and service level agreement between client and provider (NAFEA; ALMAIAH, 2021).	1 (2%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Table 2.16 – Criteria list for contracting professionals in GSD - 10/10

Code	Criteria	Description	Cited*
C292	Reuse ability	The application of reusable requirements catalogs to the development of software products implies changes in the basic Requirements Engineering process model (elicitation, analysis and negotiation, documentation or specification, and validation). The differences between the reuse-based and general process models are mild but may still lead to some process overload (NICOLÁS *et al.*, 2018).	1 (2%)
C293	Eminence Education	Eminence Education is reserved for individuals with fully developed talents who are incredibly talented in a domain relative to other highly accomplished producers and performers. This relative superiority is recognized by senior members of the domain and is usually related to sustained contributions or contributions that have had or will have a lasting and memorable impact on the domain (NICOLÁS *et al.*, 2018).	2 (3%)
C294	Lack of conviction issues	The personal conviction issue is related to someone relying on verified evidence rather than personal observation, which can be biased, error-prone, and spotty. The rigorous, demanding experimental design constraints are needed (or even morally obligated) when the findings might contradict strongly-held prior beliefs and practices. It is related to personality dimensions (DEVANBU *et al.*, 2018).	1 (2%)
C295	Gender preference and segregation	Gender segregation at work is widespread; within software engineering, the gender composition of contract workers differs significantly by occupational subspecialty. For example, women are far more prevalent in software quality assurance than in other software subspecialties (CAMPERO, 2021).	3 (5%)
C296	Work-Life Balance Issues (Women)	Work-Life Balance Issues. After the COVID-19 pandemic and suddenly working from home, women reported being pressured to work overtime, with no working hours limits, and having to attend meetings in different time zones or learn new knowledge. Thus, they would be excluded from decisions made in meetings and perceived by others as lacking in teamwork (TRINKENREICH *et al.*, 2022).	1 (2%)
C297	Benevolent Sexism (Women)	Benevolent sexism represents the subjectively positive feelings towards gender that often bring some sexist antipathy. For example, the study of Trinkenreich *et al.* (2022) reported that participants were spoiled, never receiving harsh/direct feedback, and being included in initiatives only because they were women, not because of their skills and abilities.	1 (2%)
C298	Lack of Recognition (Women)	Lack of Recognition (women). Feeling valued or appreciated is part of Maslow's hierarchy of human needs. The woman mentioned not being recognized for her work and that the women's results are usually evaluated as OK, never as excellent, even when they perform exceptional work. No praise from managers was considered one of the reasons for leaving (TRINKENREICH *et al.*, 2022).	1 (2%)
C299	Lack of Peer Parity (Women)	Being surrounded by similar individuals to compare oneself, or identifying with at least one other peer in the team, is known as peer parity. The women mentioned a [im]balance in men: women ratio and two consequences: impact on their social capital, [be]cause men to socialize in a different way than women do; and impact on developing their self-confidence due to lack of role models (TRINKENREICH *et al.*, 2022).	1 (2%)
C300	Impostor phenomenon (Women)	Impostor Syndrome describes an experience of individuals who, despite their objective successes, feel persistent self-doubt and are exposed as fraud or impostor. The women mentioned it as a challenge and reason to leave situations in which women personalize failures and feel ashamed and inferior more than men, and they tend to escape the job, but always masked as personal reasons (TRINKENREICH *et al.*, 2022).	1 (2%)
C301	Pay inequality between genders (Women)	Pay inequality between genders and inferior career growth opportunities. Men raise only their counterparts to the top layer. Lack of transparency about the laddering criteria (TRINKENREICH *et al.*, 2022).	1 (2%)
C302	Prove-it Again (Women)	Prove it Again is a bias effect that occurs when a group member who does not align with the stereotypes is measured by a stricter criterion than those who align with them. So, for example, women always need to show competence: put extra effort to be heard when there is competition between men and have no room to slip[up] (TRINKENREICH *et al.*, 2022).	1 (2%)
C303	Maternal Wall (Women)	Maternal Wall expresses the experience of mothers whose coworkers perceive and judge them as having made one of two choices: either they continue to work and neglect their family, making the motherless likable, or the mother prioritizes family over work, making them less reliable in the workplace (TRINKENREICH *et al.*, 2022).	1 (2%)
C304	Total number of technical skills (one employee)	A total number of technical skills (one employee) comprise the following capabilities information technology, business domain, project management, and sourcing managing customers or suppliers. In addition, it is a personal technical dimension related to the human resource department (GOLES *et al.*, 2009).	1 (2%)
C305	Degree of task information	The degree of task information, a content element of communication in service exchanges, is conveyed through functional duty terms. The proportion of task terms to the number of words in a message defines the degree of task information. Greater (lesser) degrees of task information decrease (increase) uncertainty (LUDWIG *et al.*, 2022).	2 (3%)
C306	Degree of personal information	The degree of personal information is a communication content element conveyed through self-disclosure terms. The ratio of self-disclosure terms to the total number of words in a message defines the degree of personal information (LUDWIG *et al.*, 2022).	1 (2%)
C307	Degree of communication concreteness	Degree of communication concreteness is a manner element of communication conveyed by perceptible, precise, or specific terms. The ratio of concrete terms to the total number of words in a message defines the degree of concreteness (LUDWIG *et al.*, 2022).	2 (3%)
C308	Degree of affective intensity	The degree of personal affective intensity is a manner element of communication conveyed through affective terms. The ratio of affective terms to the total number of words in a message defines the degree of affective intensity. It is related to personality dimensions (LUDWIG *et al.*, 2022).	1 (2%)
C309	Limited support for reusability	Usability consists of how users' features affect the use of an interactive system in the work environment. So, software reusability is an attribute that refers to the expected reuse potential of a software component. Software reuse not only improves productivity but also positively impacts the quality and maintainability of software products (MELO *et al.*, 2016).	1 (2%)
C310	Lack of long-term planning	The traditional linear approach, which refers to long-term strategic planning, assumes normal conditions in their planning process and thus implements annual or multi-year planning. However, in times of disruptive changes, this strategic planning is replaced by an iterative approach which requires a calibration between execution and planning (PRIYONO *et al.*, 2020).	1 (2%)
C311	Efficient utilization of time and computing resources	The use of cloud computing is increasing day-to-day, and the loads encountered by cloud servers are also increasing significantly. Therefore, the scarcity of resources must be minimized to maintain adequate service, bypassing potential overloads. It is, therefore, essential to reduce the load on the server so that all users have equal performance (VANITHA; MARIKKANNU, 2017).	1 (2%)
C312	E-waste minimization	The electronics industry is the world's largest and most innovative industry. However, after a time of use, it becomes a complex residue. It contains many hazardous heavy metals, acids, toxic chemicals, and non-degradable plastics. Thus, the electronics industry is still specifying the purpose of about 75% of e-waste or finding ways to use it, including refurbishment, remanufacturing, and reusing parts for repair (LAKSHMI *et al.*, 2017).	1 (2%)
C313	Green and sustainable management of product life cycle	A Green or Sustainable Product Life Management strategy could be defined as follows. First, Mission by supplying products that satisfy customer needs considering all the lifecycle impacts. Then Vision, when the company coordinates the generation, change, and storage of all the relative product metadata with metrics that will assess the sustainability of all the product lifecycle phases. Finally, the Objective is to share data, information, and knowledge of all the product lifecycle stages, to encourage collaboration with all stakeholders, and enable sustainability through Green Products and Processes (VILA *et al.*, 2015).	1 (2%)
C314	Minimal reengineering	Reengineering systems on a microservices-based architecture can be seen as implementing a service-oriented architecture (SOA). However, deploying SOA in a company is demanding, as it may implicate updating mission-critical systems with high technical debt and maintenance costs. Thus, a process is required that supplies a fine set of stages and techniques that minimize risks and simultaneously ensure the quality of the systems during the migration process (SILVA *et al.*, 2022).	1 (2%)
C315	Polymorphic design	Agile software developers focus on polymorphic designs that meet the project's long-term goals. The sustainability of a software project can be compromised if agile software developers do not consider the impact of straightforward and polymorphic design in software development. These features of agile methods support the development of green and sustainable software (RASHID; KHAN, 2018).	1 (2%)
C316	Team Empowerment	Team empowerment is defined as the collective belief in a group that it can be effective and its role in determining the group's effectiveness. Empowerment is the delegation of authority and decision-making responsibilities, strengthening the role of people and teams (GARRO-ABARCA *et al.*, 2021).	1 (2%)
C317	Metrics to assess risk-based testing	Metrics to assess risk-based testing is to assess how many risks we mitigated through risk test cases. In addition, it allows checking how many risks we mitigated per requirement. Finally, identifying prioritized risks allows us to confirm prioritized risks with the highest level of requirements (BASTIDAS *et al.*, 2021).	1 (2%)
C318	Metrics to assess risk-based testing activities (time)	Metrics to assess risk-based testing time identification allows knowing the average time taken to analyze a requirement with a certain number of lines. Assessing risk identification activity allows setting useful or meaningful risks to develop test cases (BASTIDAS *et al.*, 2021).	1 (2%)
C319	Training of DevOps activities	Training in DevOps activities have a positive impact while implementing DevOps. Formal training sessions are required to understand the concept and DevOps environment properly. The organization must support its teams with training sessions to help their organization successfully work on DevOps activities (RAFI *et al.*, 2020a).	1 (2%)

*The last column represents the times and percentage that the criteria were cited.

Source: author.

Word cloud made by the SLR documents abstracts. From this figure, we can indicate the analyzed data's compatibility. As we can see in the figure, the words with more evidence in

Table 2.17 – SMART 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".

Source: author.

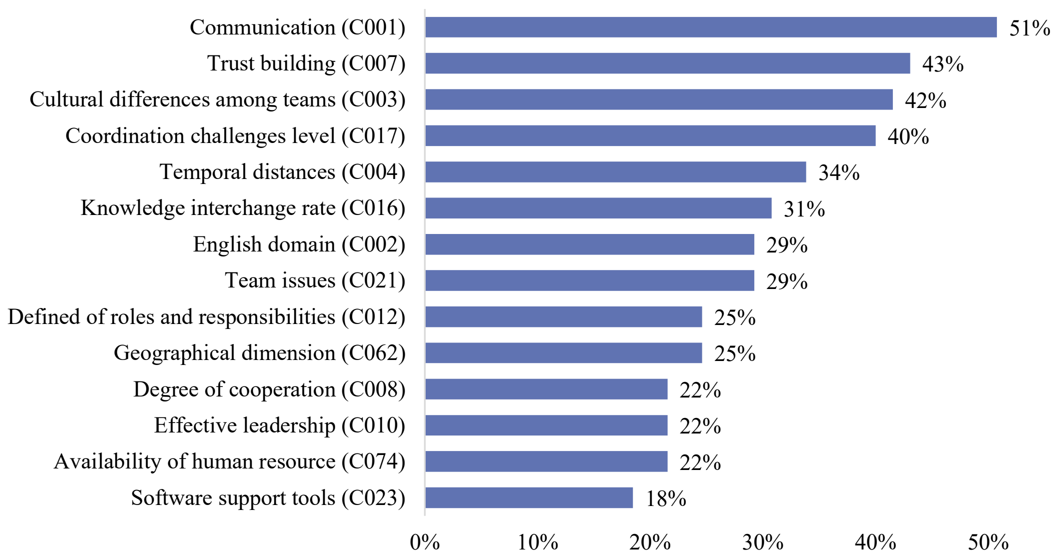


Figure 2.3 – Top 14 highly cited criteria in the SLR

Source: author.

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. 2.3 - Top 14 highly cited criteria in the SLR.

Additionally, we apply the bibliometrix package in R and RStudio software to make a more consistent analysis, as shown in the following Subsection 2.1.2.4.

2.1.2.4 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

Figure 2.4 – Word cloud made by the SLR documents abstracts

Source: author.

perspectives, not for only one like as the challenges (RAFI *et al.*, 2020b), or success factors (ILYAS; KHAN, 2016), or barriers (SHAMEEM *et al.*, 2020). 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) (AMMAD *et al.*, 2019), or "participation, acceptance, and learning incentive of innovative technology" (C154) (GOPAL *et al.*, 2018), or "lifelong learning" (C289) (KLUGE *et al.*, 2020a). Furthermore, pass through the supply responsiveness as "behavioral skills at dealing with changing/ flexibility" (C116) (GOPAL *et al.*, 2018), or "frequent information sharing among oversees practitioners" (C275) (AKBAR *et al.*, 2020a; KLUGE *et al.*, 2020a), and, without forgetting the technical issue as "insufficiently defined or lack of conformance to shared practices across sites" (C225) (SIEVI-KORTE *et al.*, 2019), and "interfacing with different layers of development framework" (C120) (HIDAYATI *et al.*, 2020).

Fig. 2.5 plots the Authors' production over time (publications number and total citations per year), as the bibliometric analysis proposed by Aria e Cuccurullo (2017). In this Figure, we show the fourteen 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 M.A. with eight publications (12.3% of documents found) and Khan A.A. with five publications (7.7%), but they worked together in three opportunities (KHAN; AKBAR, 2020; AKBAR *et al.*, 2020; AKBAR *et al.*, 2020b). The author Khan S.U. has six publications (9.2%), whereas five (7.7%) worked together with Ilyas M. (RASHID *et al.*, 2021; ILYAS; KHAN, 2017; ILYAS; KHAN, 2012; ILYAS; KHAN, 2016; KHAN *et al.*, 2019). Nevertheless, Viscaíno A. worked alone with the authors of this SLR in four documents (6.2%). Alsanad A. and Gumaei A. have three publications (4.6%) together with Akbar M.A. (AKBAR *et al.*, 2020b; RAFI *et al.*, 2020b; AKBAR *et al.*, 2020a); as the author Shameem M. with the

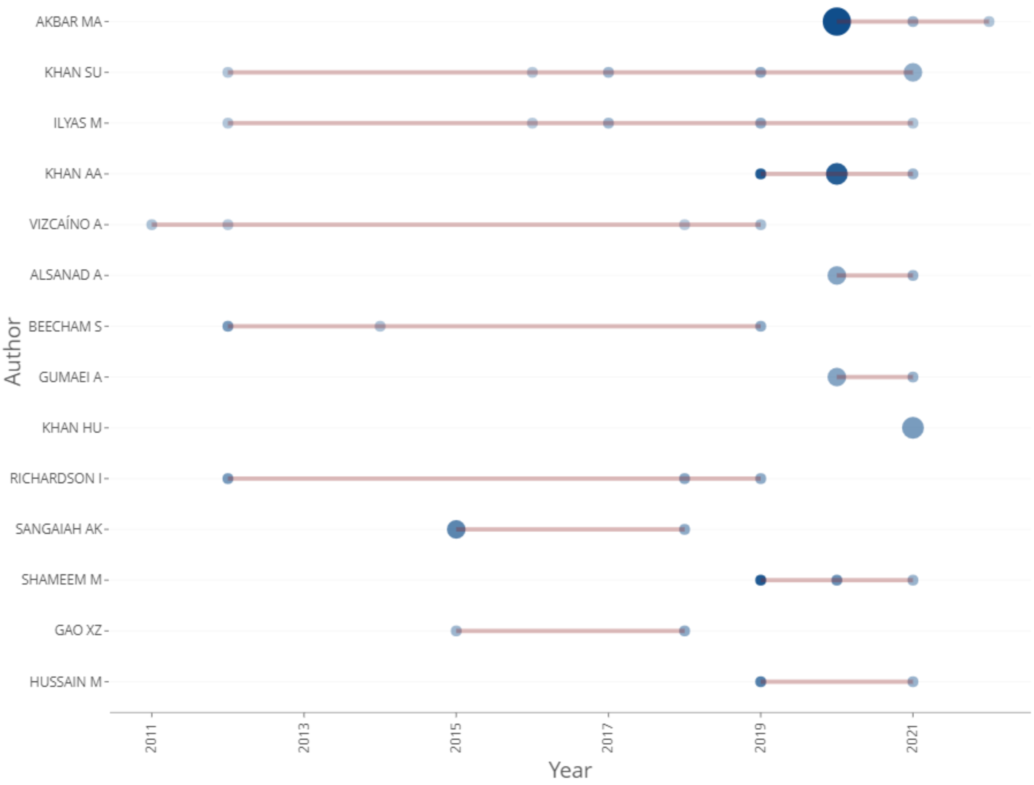


Figure 2.5 – Authors' production over time

Source: author.

same number of publications jointly Khan A. A (AKBAR *et al.*, 2020b; KHAN *et al.*, 2019; SHAMEEM *et al.*, 2020). The other authors in the Figure 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. 2.6, as we can see a publication concentration in the last three periods, considering that SLR finished on September 9th, 2022. Confronting Fig. 2.5 - Authors' production over time and Fig. 2.6 - Annual scientific production by region, we can also notice the publications concentration in the last three years by the prominent authors.

The geographical distribution of the database (based on the first author's country) highlights the countries Pakistan with thirteen documents (20%), China with eleven documents (16.9%), and India with seven documents (10.8%). The other countries are USA 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, as shown in Fig. 2.6 - Annual scientific production by region. Outlining, Asia concentrates 55%, Europe 25%, North America 9%, Australia 6%,

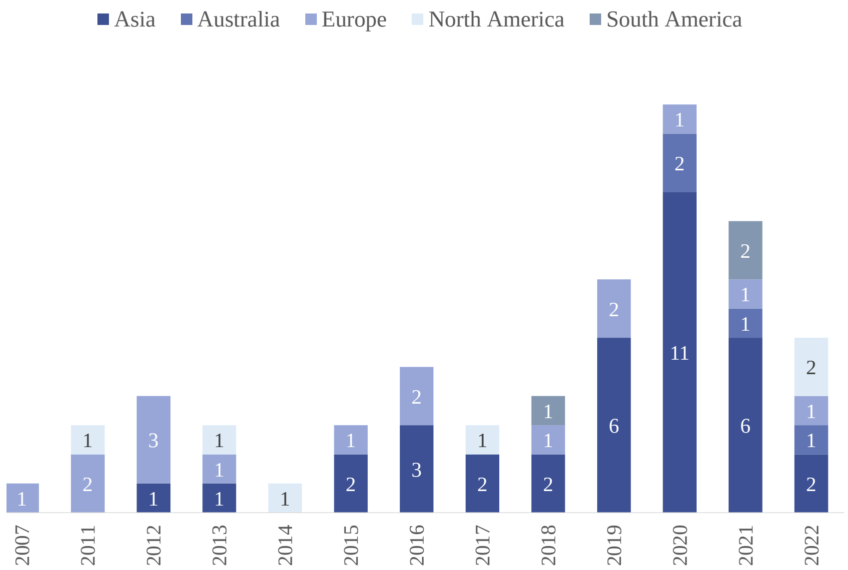


Figure 2.6 – Annual scientific production by region

Source: author.

and South America 5% of the publications.

Another relevant information is the evolution of the criteria citation by year, as shown in Table 2.18. For each criterion, this table shows the citation intensity. The darker line represents the year in which the authors most frequently cited the criterion. Accordingly, in 13 of 14 main criteria (see Fig. 2.3 - Top 14 highly cited criteria in the SLR.), or 93%, the concentration is on the last four years, which confirms the importance of this topic to the academic community that may, at least, grow up in a period of disruption of global supply chains provoked by the pandemic.

Table 2.18 – The evolution of criteria citation

	2007	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2022	citation
Communication (C001)	1	2	4	2	1	1	2	3	1	6	5	5	33
Trust building (C007)	1	1	2	2		2	2	1	1	4	7	5	28
Cultural differences among teams (C003)	1	1	4	1	1	1	2	2	1	6	3	4	27
Coordination challenges level (C017)	1	2	3	1		1	2	2	2	5	2	5	26
Temporal distances (C004)	1		3	1	1	1	1	1	1	5	3	4	22
Knowledge interchange rate (C016)			2	1		1	3	1	2	4	3	3	20
Team issues (C021)	1	1	3	1			1	1	1	4	4	2	19
English domain (C002)	1	1	3	1	1		1		1	5	2	3	19
Geographical dimension (C062)		1	1	1	1	1	1		1	4	2	3	16
Defined of roles and responsibilities (C012)	1		2			1	2			4	4	2	16
Availability of human resource (C074)	1		1				1	2		3	2	4	14
Effective leadership (C010)	1	1	2				2	1		1	3	3	14
Degree of cooperation (C008)	1		1	1			2	1		1	3	3	14
Software support tools (C023)			3	1				1	2	2	2	1	12

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

Source: author.

Aiming to assess the database's quality, we ranked the related sources based on their classification. We collected this information directly from the Scopus source database. This source's quality index has four quartiles Q1, Q2, Q3, and Q4. Q1 is the first quartile, including sources with very high impact, and, following the category, Q4 is the last quartile, which includes the journal with slight 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 (ILYAS; KHAN, 2012; CHATZIPETROU *et al.*, 2011) come from the two databases (Scopus and Web of Science). They are old conferences in the 19th edition and 42nd editions, respectively. As for the source, (HUMAYUN; CUI, 2013) 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 subsection, we show the co-citation network.

2.1.2.5 The co-citation network

We use the bibliometrix package (ARIA; CUCCURULLO, 2017) in R and RStudio software (RStudio Team, 2021) to build the co-citation network figure and analysis. 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. We separated the SLR co-citation network in Fig. 2.7 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.

Therefore, through snowball searches (WOHLIN *et al.*, 2022; WOHLIN *et al.*, 2020), we did a complete reading of all co-citation network documents searching for new attributes or criteria not identified in the primary SLR documents, aiming to complete the criteria database.

We start analyzing the authors in color blue in Fig. 2.7 - The SLR co-citation network, and the GSD theme is directly related to 60% of the Authors. Rising by the others, 40%, not related to GSD, where Corbin J. M. (CORBIN; STRAUSS, 1990) and Finstad K. (FINSTAD, 2010) made the studies concerning the research methodologies, Afzal W. (AFZAL *et al.*, 2009) focused on software testing. Kitchenham B. (KITCHENHAM; CHARTERS, 2007; KITCHENHAM *et al.*, 2002) dedicated to proposing a method for SLR in software engineering. In this blue association, the collaboration network is evident with Niazi M. and Khan S. U., where the first start analyzing critical success factors in the software process (NIAZI *et al.*, 2006). Next, Khan S. U. made an SLR identifying barriers and competitive factors in GSD (KHAN *et al.*, 2011a) and (KHAN *et al.*, 2011b). Furthermore, in this blue group, Khan A. A. (KHAN *et al.*, 2012) propose 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. 2.7 refers to the GSD subject. The most cited authors in the red group are Carmel E. and Herbsleb J. D., where the first author wrote a book in 1999 (CARMEL, 1999) addressing the GSD team, and he made a paper approaching the distance

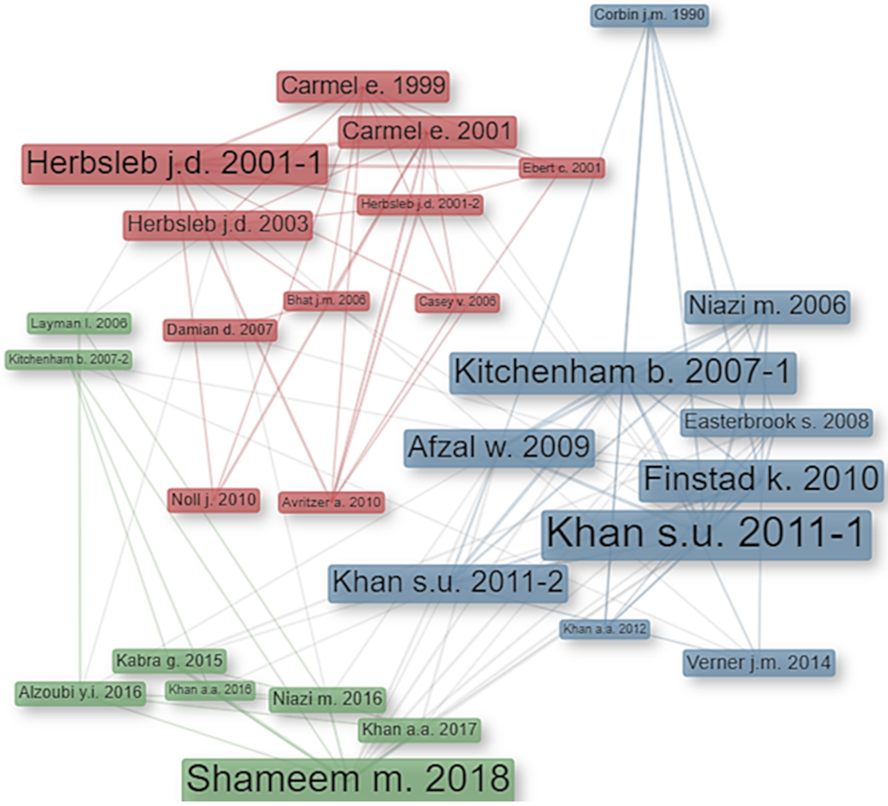


Figure 2.7 – The SLR co-citation network

Source: author.

issues in GSD (CARMEL; AGARWAL, 2001). In addition, Herbsleb J. D. made two documents in this group in 2001, a magazine paper addressing the effects of physical separation in GSD teams (HERBSLEB; MOITRA, 2001). Also, he analyzed the delay and communication in GSD through an empirical study in the same-site and cross-site; he stated that, for similar tasks in cross-site, it takes about two and one-half times as long to complete compared to same-site (HERBSLEB *et al.*, 2001). 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 co-citation group in Fig. 2.7, with Shameem M., who investigated the challenges for agile GSD using an online questionary and prioritized the category challenges through an analytic hierarchy process (AHP) (SHAMEEM *et al.*, 2018), also worked together with Khan A. A. who has more two works in this green group. In both works, Khan A. A. investigated the software process improvement barriers (KHAN *et al.*, 2017; KHAN; KEUNG, 2016). Moreover, Niazi M. (NIAZI *et al.*, 2016) made a sturdy questionnaire to validate the management's challenges in GSD, and Alzoubi Y. (ALZOUBI *et al.*, 2016) investigated the communication challenges and the techniques used to overcome those challenges in Agile GSD. Only Kabra G. (KABRA *et al.*, 2015) did not study the GSD subject in this green group.

Summarising, the authors studied communication, challenges, and SPI barriers in the GSD context.

Afterward, however, we did not find any new criteria after completing the co-citation network studies. Subsequently, we present the criteria-gathering process.

2.1.2.6 The definition and the criteria gathering process

In this subsection, we first present the criteria-gathering process based on the approach of the studies and authors, as shown in Annex B by the Tables B.1, B.2, and B.3. Some authors, Richardson *et al.* (2012), Sangaiah *et al.* (2015b), and Iqbal *et al.* (2022), get the criteria from previous work. In many cases, the authors: Kamal *et al.* (2020), Hidayati *et al.* (2020), Imtiaz e Ikram (2017), Bhatti e Ahsan (2016), Baldwin e Damian (2013), Sievi-Korte *et al.* (2019), Vizcaíno *et al.* (2018), Šablis e Šmite (2016), and Shameem *et al.* (2020) made a simple literature review or a systematic literature review; similarly as the authors: Ilyas e Khan (2017), Khan e Akbar (2020), Akbar *et al.* (2020a), Lai *et al.* (2020) and Hussain *et al.* (2021), but, they after surveyed to validate the methodology proposed. Ilyas e Khan (2012) and Dumitriu *et al.* (2011) only did a literature review, and Yaseen *et al.* (2016), Defranco e Laplante (2017) and Alsanoosy *et al.* (2020) did a systematic literature review. Lastly, Kluge *et al.* (2020a) and Humayun e Cui (2013) were only surveyed to collect the criteria.

We summarize some documents from the SLR database. Hassan *et al.* (2019) highlight the current issues of GSD and provide policy recommendations to mitigate them. The paper 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.* (2016) 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.* (2012) conducted 19 interviews with experts from 14 US, Spain, and Indian companies. They point out 23 risk factors. Finally, Kroll *et al.* (2018) investigate the existing empirical evidence about Follow the Sun (FTS). FTS is a particular case of GSD, where software development occurs over a twenty-four-hour working day. The authors' main contribution was the table that identifies and links the research topic and gaps by mapping the papers' research problems.

The definition of criteria was a weakness in many studies. The authors defined criteria entirely in 10.8% of the documents, partially in 35.4%, and did not define them in 53.8% of the documents. The results may suffer interference due to the lack of description of the criteria, especially when the authors group them and apply the questionnaire responses, whether by researchers or professionals, to prioritize the criteria. Only seven papers made a full criteria definition, namely: Nidhra *et al.* (2013), Richardson *et al.* (2012), Ammad *et al.* (2019), Trinkenreich *et al.* (2022), Ludwig *et al.* (2022), Garro-Abarca *et al.* (2021), and Bastidas *et al.* (2021).

The researchers' biggest challenges on the SLR database were identifying, categorizing, grouping, and scientifically prioritizing the criteria. This subsection showed the identifying process. The following subsection presents the authors' effort to apply scientific approaches to categorize, group, or prioritize as Multi-Criteria Decision-Making (MCDM) methods.

2.1.2.7 Multicriteria decision-making and multivariate statistical analysis approaches

Multi-criteria 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, which demonstrates the growth of the approach. 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.* (2018), as shown in Subsection 2.1.2.2, found 11 groups, and the "Trust" group was the more important group of situational factors in GSD. Khan *et al.* (2019), 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.* (2020b), analyzed the RCM activities, collected 23 success factors from SLR, made a questionnaire, grouped them in 4 categories, and used FAHP to determine that "Process" was the category most important. Then, Akbar *et al.* (2020) 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.* (2015b) used 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.* (2015a) 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.* (2018), 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.* (2019), 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 multi-attribute decision-making (FMADM) approach to forecasting the possibility of a successful offshore software development outsourcing relationship.

Goyal e Gupta (2020) 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 precise selection of team members under GSD and later rank them using intuitionistic fuzzy to the aggregate opinion of various experts. They used intuitionistic fuzzy Muirhead Mean (IFMM) to aggregate the intuitionistic criteria.

Nurrahman *et al.* (2021) explored the influencing factors in selecting software development methodology and prioritizing them for the online gig economy project. Using the standard AHP, the authors state that the Requirement is the highest priority when developing software in the GE, followed by User Involvement, Documentation, and Personnel.

Through an SLR, Rafi *et al.* (2022) identified 16 situation factors of DevOps. Then mapped into DevOps basic principles and verified with industrial practitioners by conducting a questionnaire survey. Moreover, they applied the PROMETHEE-II technique to analyze 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.* (2019) used Principal Component Analysis (PCA), and Chatzipetrou *et al.* (2011) used a Hierarchical Cluster Analysis (HCA). Sundararajan *et al.* (2019), based on literature, 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 methodology that takes an affirmative approach to analyze a structural theory. The SEM allows the researcher to model complex relationships that are not possible with other multivariate techniques (SUNDARARAJAN *et al.*, 2019).

Chatzipetrou *et al.* (2011) made an empirical study of 65 individuals in a GSD environment to prioritize 24 software quality aspects. They use the Hierarchical cluster analysis to prioritize the data. Hierarchical cluster analysis (HCA) is a multivariate statistical procedure that attempts to identify relatively homogeneous groups of individual cases based on their values of a standard set of variables (CHATZIPETROU *et al.*, 2011). It also uses this value to describe them. They concluded that the stakeholders show to create clusters of aligned understanding of priorities according to personal and cultural views rather than their roles in software development.

From the documents cited above, we may see a variety of results. However, as stated by Gulzar *et al.* (2018), numerous aspects of different criteria variations have concerned researchers in general, and, to date, the outcomes in the GSD environment have been either contradictory or insufficient. For example, some researchers have recognized that cultural differences are significant because they substantially impact GSD, while others did not consider culture significant.

In the following subsection, 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 Affinity diagram tool gathers large amounts of language data (ideas, opinions, issues) and organizes it into groupings based on the natural relationship between items. It is considerably more of a creative process than a relational one. This method allows for organizing qualitative data collected from customers and other stakeholders to understand themes, issues, and concerns (GKATZIDOU *et al.*, 2021; ANJARD, 1995). However, we employ the NLP techniques, and *k*means clustering for a more analytical quantitative method of clustering attempt.

2.2 Natural language processing

In this subsection, we present Natural Language Processing (NLP). NLP investigates how we can utilize computers to understand and operate natural language text or speech to get things done. In addition, develop appropriate tools and techniques to make computer systems understand and manage natural languages to perform the expected assignments (CHOWDHURY, 2003). Furthermore, this section presents how to source text data is represented in numerical vectors to be used in machine learning and also shows the leading algorithms.

2.2.1 General definition

Natural Language Processing (NLP) employs computational techniques to learn, understand, and produce human language content. NLP is a theoretically motivated range of computational techniques for analyzing and representing naturally occurring texts at one or more levels of linguistic analysis (LIDDY, 2001; BIRD *et al.*, 2009; HIRSCHBERG; MANNING, 2015).

At one extreme, it could be as simple as counting word frequencies to compare different writing styles. At the other extreme, NLP involves "understanding" complete human utterances, at least to the extent of being able to give proper responses to them.

Applications of NLP include several fields of study, such as neural machine translation, chatbots, questions and answers (Q&A), natural language text processing and summarization, user interfaces, multilingual and cross-language information retrieval (CLIR), speech recognition, artificial intelligence, image captioning, video captioning, and expert systems. In addition, NLP has become quite prominent due to the proliferation of the world wide web and digital libraries (BIRD *et al.*, 2009; DEVLIN *et al.*, 2018).

Furthermore, other applications of NLP applications, together with Information Retrieval (IR), structure and unstructured Data Mining (DM), and machine learning techniques, comprise: sentiment analysis, opinion mining, subjectivity analysis, uncovering deception and lies hidden in the text (RAVI; RAVI, 2015; JORDAN; MITCHELL, 2015).

The core methods of most widely used machine-learning methods are supervised methods and systems, including spam classifiers of e-mails, face recognizers over images, and diagnosis systems for patients. Hence, the training data form a collection of *(x, y)* pairs, and the goal is to produce a prediction $y*$ in response to a query $x*$ (JORDAN; MITCHELL, 2015). Indeed, NLP is a powerful tool widely used (WANG *et al.*, 2019).

Statistical NLP has emerged as the immediate option for modeling complex natural language assignments. Nevertheless, in its conception, it often suffered from the notorious curse of dimensionality while learning the combined probability functions of language models. These led to the motivation to learn distributed representations of words existing in low-dimensional space (YOUNG *et al.*, 2018).

Word Embedding and TF-IDF (term frequency-inverse document frequency) are two of the most common methods in Natural Language Processing (NLP) to convert sentences to machine-readable code.

2.2.2 Word embedding

Word embedding techniques represent the words mathematically and are a real-valued vector representation of words by embedding semantic and syntactic meanings obtained from a large unlabeled corpus (WANG *et al.*, 2019). Word embeddings are distributed representations that model properties of words into vectors of real numbers and capture syntactic characteristics and semantic word relationships. The word embeddings follow the distributional hypothesis: words with similar meanings tend to occur in similar contexts. Thus, these vectors try to capture the characteristics of a word's neighbors as similarities. Measuring similarity between vectors is possible using measures such as cosine similarity (DESSI *et al.*, 2020).

Word Embedding converts a word to an *n*-dimensional vector. The practitioners often used word embeddings as the first data processing layer in a deep learning model (YOUNG *et al.*, 2018). Word embeddings are an efficient method for solving various NLP tasks in recent years, enabling various machine learning models that rely on vector representation to enjoy richer text input representations while alleviating high-dimensionality issues (PISKORSKI; JACQUET, 2020). Fig. 2.8 - Word embeddings exhibit compositionality represent a word embedding, where the darkest fields illustrates the *dimensional vector* of each word. Thus, by the Figure, if we add *King* and *Woman* minus *Man* we got *Queen*.

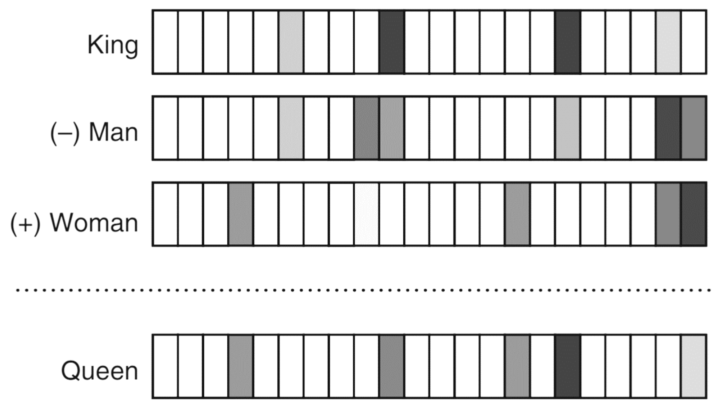


Figure 2.8 – Word embeddings exhibit compositionality

Source: Young *et al.* (2018).

There are two main approaches for learning word embedding, both counting on contextual knowledge. The first is a count-based vector space model, unsupervised, based on matrix factorization of a global word co-occurrence matrix. In this model, raw co-occurrence counts do not work well, so we desire to do clever things on top. The models map count-based statistics like co-occurrences between neighboring words to small and dense word vectors. PCA, topic models, and neural probabilistic language models are outstanding examples of this category (WENG, 2017).

Unlike the count-based approaches, context-based methods produce predictive models that directly target predicting a word given its neighbors. The dense word vectors are part of the model parameters. The best vector representation of each word is learned during the model training process. Some models used are a skip-gram model, continuous Bag-of-Words (CBOW), Co-occurrence matrix, FastText, N-gram model, Dictionary model, and Deep contextualized model (WENG, 2017; WANG *et al.*, 2019).

2.2.3 TF-IDF

The Bag of Word model is one of the popular models to represent the document in Vector Space Model. It represents the documents in *n*-dimensional vector space where *n* is the number of unique words, and its weight is calculated by the term frequency-inverse document frequency (TF-IDF) weighting scheme (SINGH *et al.*, 2022).

The TF-IDF, or TFIDF, represents the degree of significance of each term in the lattice object set, which is given to the classifier (MAHARJAN, 2018; ZHANG *et al.*, 2011). TF-IDF was the most helpful representation method for textual data and therefore remains the baseline approach for any innovative method of classifying text across multiple domains (DESSI *et al.*, 2020). The TF-IDF's primary purpose in any document is to split the words into relevant terms or not to the central document's topic (SJARIF *et al.*, 2019). TF-IDF converts a list of text documents to a matrix representation, each document is converted to a row of the TF-IDF matrix, and each word is stored in a column vector.

TF-IDF is the method used in the Vector Space Model, particularly in the information retrieval (IR) domain, including text mining. The practitioners often used the Vector space models to represent text (although they can represent any object) as a vector of identifiers. These algebraic models can identify whether multiple texts are equivalent in meaning, regardless of sharing the exact words. It is a statistical method to measure the significance of a word in the document to the whole corpus (SAFIE *et al.*, 2018).

We calculated the term frequency to the number of events a word arises in the document. It is usually normalized in a positive quadrant between 0 and 1 to eliminate bias toward lengthy documents. Then, we removed the punctuation, and all text is lowercase during tokenization to create the index of terms in TF-IDF. The first two letter TF or term frequency refers to how important if it occurs more frequently in a document. Therefore, the higher TF, the more estimated the term is significant in respective documents. Likewise, we computed the IDF or Inverse Document Frequency on how infrequent a word or term is in the documents (SJARIF *et al.*, 2019).

The weighted value is estimated using the whole training dataset. The idea of IDF is that a word is not considered an excellent candidate to represent the document if it frequently occurs in the whole dataset as it might be the stop words or common, generic words. Hence, only a few words in contrast to the entire dataset are relevant for those documents (SAFIE *et al.*, 2018).

TF-IDF not only assesses the importance of words in the documents but also evaluates the importance of words in a document database or corpus. In this sense, the word commonness in the document will increase the weight of words proportionally but offset the corpus's word frequency (SJARIF *et al.*, 2019; SAFIE *et al.*, 2018).

The classic formula for TF-IDF (MAHARJAN, 2018; ZHANG *et al.*, 2011) is given by Equation 2.1:

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right) \tag{2.1}$$

where, $w_{i,j}$ is the weight for term i in document j, N is the number of documents in the corpus, $tf_{i,j}$ is the term frequency of term i in document j and df_i is the document frequency of term i in the corpus (REBELO *et al.*, 2021).

Table 2.19 - Comparison of word embedding and TF-IDF shows the difference behind word embeddings versus TF-IDF vectorization.

Table 2.19 – Comparison of word embedding and TF-IDF

Word embedding	TF-IDF
Multidimensional vector which attempts to capture a word's relationship to other words	Sparse matrix where each word maps to just a single value, captures no meaning
Often trained on a large external corpus	Trained without external data
Must be applied to each word individually	Can be applied to each training document at once
More memory-intensive	Less memory intensive
Ideal for problems involving a single word such as a word translation	Ideal for problems with many words and larger document files

Difference behind using word embeddings versus TF-IDF matrices.

Source: Adapted from Sjarif *et al.* (2019) and Safie *et al.* (2018).

2.2.4 Clustering analysis and algorithms

We present in this subsection the meaning of cluster analysis and an overview of the cluster algorithms.

2.2.4.1 Clustering analysis

Before discussing clustering, let us first discuss pattern detection and classification tasks. Pattern detection is a central part of Natural Language Processing. These observable patterns (word structure and frequency) correlate with particular aspects of meaning, such as tense and topic. However, how did we know where to start looking? Which aspects of form to associate with which aspects of meaning? In this context, classification is the task of choosing the correct class label for a given input. In primary classification tasks, we consider each input in isolation from all other inputs and define the set of labels in advance (BIRD *et al.*, 2009). Finally, cluster analysis aims to decrease the dimensionality of a dataset by identifying homogenous groups of data (BACH *et al.*, 2020)

Cluster analysis, or simply clustering, divides a set of objects into a group of similar subsets (called a cluster) concerning a given similarity measure (MAHARJAN, 2018). Clustering or data segmentation is a process of grouping (partitioning) large data sets into groups (partitions) according to their similarities (GUSTRIANSYAH *et al.*, 2020). Clustering is the problem of finding a partition of the observed data without explicit labels indicating the desired partition (KOU *et al.*, 2014). The clustering of data instances resulted in groups with similar in-between features, while the data instances in different groups had significantly different features (BACH *et al.*, 2020). The investigations started with document clustering focused on improving performance measures and efficiency in 1979. Then, to increase the efficiency of information retrieval searches in 1985 and clustering in browsing documents in 1992. Nowadays, practitioners apply clustering in multiple domains such as machine learning, pattern recognition, image analysis, information retrieval, bioinformatics, data compression, computer graphics, archaeology, psychology, and marketing (MAHARJAN, 2018).

The first step in cluster analysis is determining the features of the variables used to segment the data. Then the cluster variables are usually selected concerning the theory and the specific research subject. The second step in cluster analysis is to select the clustering method. The practitioners use several clustering methods, like the k-Means and mini-batch k-Means clustering approach. These methods are the most employed due to their capacity to achieve a stable solution, improving the outcomes' trustworthiness. The third step in cluster analysis is choosing the number of clusters. In k-Means, the analyst should choose the number of clusters, employing the various rules or expert knowledge. Finally, after the cluster solution was found, clustering results can be interpreted concerning the underlying theory and research domain (BACH *et al.*, 2020). Finally, we can analyze clustering results related to the underlying theory and research domain after finding the clustering solution. Fig. 2.9 displays the steps in cluster analysis.

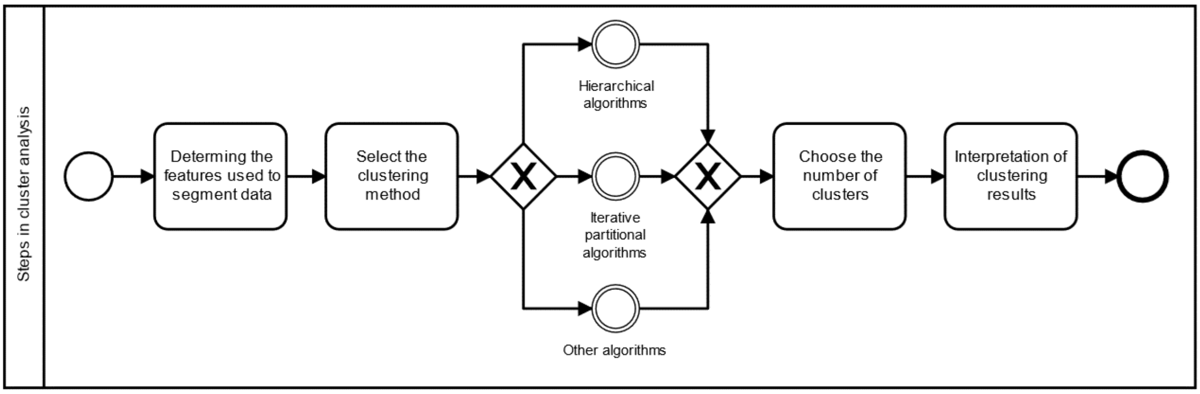


Figure 2.9 – Main steps in cluster analysis

Source: Bach *et al.* (2020).

2.2.4.2 Clustering algorithms

A clustering algorithm separates the set of word vectors into n different categories (WANG *et al.*, 2019). A wide range of clustering procedures has been developed based on specific assumptions regarding the nature of a "cluster". The concern with computational complexity is paramount in both clustering and dimension reduction. The goal is to exploit the massive data sets available if one dispense with supervised labels (JORDAN; MITCHELL, 2015).

It is often difficult to categorize the clustering algorithms into defined categories, as they may contain characteristics of several categories. Nevertheless, clustering algorithms can be classified into partitioning, density-based, hierarchical, grid-based, model-based, frequent-pattern-based, and constraint-based (KOU *et al.*, 2014). Within several techniques, practitioners' most popular clustering algorithms are hierarchical agglomerative and iterative partitional clustering. Single, average, complete, centroid, and Ward linkage for hierarchical and the k-Means technique for partitional clustering stand out for these techniques (GOVENDER; SIVAKUMAR, 2020).

We present the Ward linkage in the following Subsection 2.2.4.3, an agglomerative hierarchical algorithm. Then, we present the iterative partitional clustering k-Means (See Subsection 2.2.4.4) and mini-batch k-Means (See Subsection 2.2.4.5).

2.2.4.3 Ward linkage

In Agglomerative hierarchical clustering, we summarize the clusters at diverse levels, checking out their similarities and differences (SHARMA *et al.*, 2019). There are different proximity measures (aggregation) used for combining clusters in agglomerative hierarchical algorithms. Standard ones enclose single, complete, average, centroid, and Ward linkage (GOVENDER; SIVAKUMAR, 2020).

Ward linkage (or Ward minimum variance method) is the smallest increase in the within-cluster sum of squares due to merging two clusters. Moreover, the method considers every possible union of a cluster at every step, and those two clusters are combined, whose merger results in a minimum increase in information loss. Ward used the "Sum of Square" (ESS) criterion to define information loss and combine these clusters into a group where the variance is minimal. This technique stands the most frequently applied in hierarchical clustering (SHARMA *et al.*, 2019; GOVENDER; SIVAKUMAR, 2020).

For example, Ward's distance between two clusters A and B having centers a and b and frequencies n_A and n_B is given by Equation 2.2:

$$d(A,B) = \frac{d(a,b)^2}{n_A^{-1} + n_B^{-1}}, \tag{2.2}$$

where a and b are the centroids of clusters A and B (TUFFÉRY, 2011).

The output of a hierarchical clustering algorithm is a dendrogram, which is a two-dimensional tree-like structure depicting the sequence of nested clusters (GOVENDER; SIVAKUMAR, 2020).

2.2.4.4 k-Means

Non-hierarchical or partitional clustering methods create all clusters simultaneously by partitioning the data. The basic idea of this clustering algorithm category is to regard the center of data points as the center of the corresponding cluster (XU; TIAN, 2015). The main advantage of these methods is that their complexity is linear; their execution time is proportional to the number i of individuals. Hence, they can be used with large volumes of data. Furthermore, the number of iterations required to minimize the sum of squares within the cluster is usually small, making these methods even more suitable for such applications (TUFFÉRY, 2011).

Although several other clusterings algorithms have been developed since then, k-Means remains one of the most widely used methods owing to its simplicity, ease of implementation, the speed of selecting the cluster center, and efficiency (GOVENDER; SIVAKUMAR, 2020; GUSTRIANSYAH *et al.*, 2020).

The k-means algorithm seeks to divide m objects in n dimensions into k (where $k <= n$) partitions (or clusters), minimizing the sum of squares within the cluster. The resulting intra-cluster 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 (GOVENDER; SIVAKUMAR, 2020; GUSTRIANSYAH *et al.*, 2020).

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 in Equation 2.3:

$$WSS = \sum_{j=1}^{k} \sum_{i \in y_j}^{n} ||x_i^j - y_j||^2, \tag{2.3}$$

where k is the number of clusters, n is the number of objects, x_i is the i^{th} element in the cluster, and y_j is the centroid of the j^{th} cluster (GUSTRIANSYAH *et al.*, 2020). 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 (MAHARJAN, 2018).

Fig. 2.10 shows the data clustering steps using the k-Means method (GUSTRIANSYAH *et al.*, 2020; GOVENDER; SIVAKUMAR, 2020; ZEEBAREE *et al.*, 2017), as follows:

1. Determine the number of clusters k;
2. Initialize k values as cluster centers (centroids) randomly;
3. Group each data into the closest cluster. We calculate the proximity of two data using Euclidean distance;
4. Recompute each centroid by computing the mean of all centroid data with current cluster members;
5. Re-clustering each data (back to step 3) using all new centroids until all centroids do not change anymore;

6. If the centroid has not changed again, the clustering process is complete.

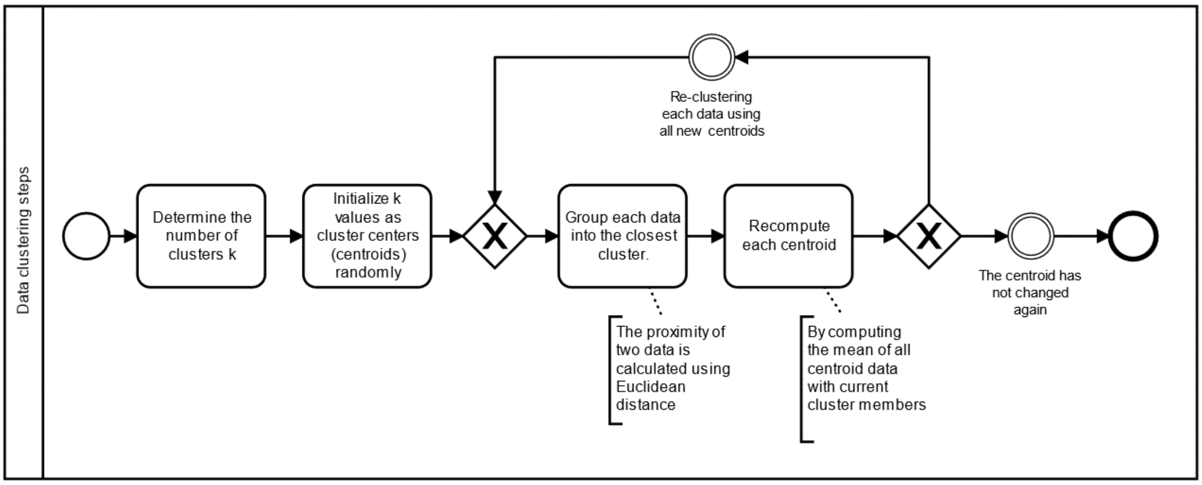


Figure 2.10 – The iterative partitional data clustering $k$means steps

Source: Gustriansyah *et al.* (2020), Govender e Sivakumar (2020), and Zeebaree *et al.* (2017).

One of the central problems of the k-Means method is selecting the optimal number of clusters k. There is no guarantee that k-means finds the global minimum, but it does find a local minimum for a given initial choice 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 (KOU *et al.*, 2014; GOVENDER; SIVAKUMAR, 2020).

2.2.4.5 Mini-Batch k-means

The Mini-Batch k-means is a variant of the k-means algorithm that employs mini-batches to decrease computation time while attempting to optimize the same objective function. Mini-batches are subsets of the input data, randomly sampled in each training iteration. These mini-batches drastically decrease the computation demanded to converge to a local solution. In contrast to other algorithms that reduce the convergence time of k-means, Mini-Batch k-means produces results that are generally only slightly worse than the standard algorithm (MAHARJAN, 2018; FEIZOLLAH *et al.*, 2014; HICKS *et al.*, 2021).

The mini-batch k-means does not utilize all the data records in the dataset each time but chooses a subset of records randomly from the dataset, dramatically decreasing the clustering time and reducing the convergence time overall (PENG *et al.*, 2018). The mini-batch has fast performance, suitability for large-scale processing and generally good quality of the resulting clustering (ANISIMOVSKIY *et al.*, 2018).

However, as the size of the dataset starts to increase, it loses its performance in clustering such a large dataset since it requires the whole dataset in the main memory (SHAHABI *et al.*, 2021).

Through "divide and conquer", the data is logically split into multiple small batch data subsets. In other words, the algorithm does not need to perform a calculation on all data samples in the calculation process. However, it randomly extracts subsets of data when the algorithm is trained. This process can significantly reduce the computation time for data. At the same time, Mini Batch k-Means also tries to optimize the objective function (XIAO *et al.*, 2018), similar to k-Means, as Equation 2.4:

$$SSE = \sum_{i=1}^{k} \sum_{j \in Y_k} dist(x, y)^2, \tag{2.4}$$

k represents k clustering centers, y_i represents the centroids, x represents the sample points, and *dist* represents Euclidean distance. We calculate the optimization function by computing the Euclidean distance, the sum of squared errors (even if the Sum of the Squared Error, SSE). Finally, Fig. 2.11 - Clustering algorithm comparison: (a) k-Means, (b) Mini-batch k-Means compares the above two algorithms' principles.

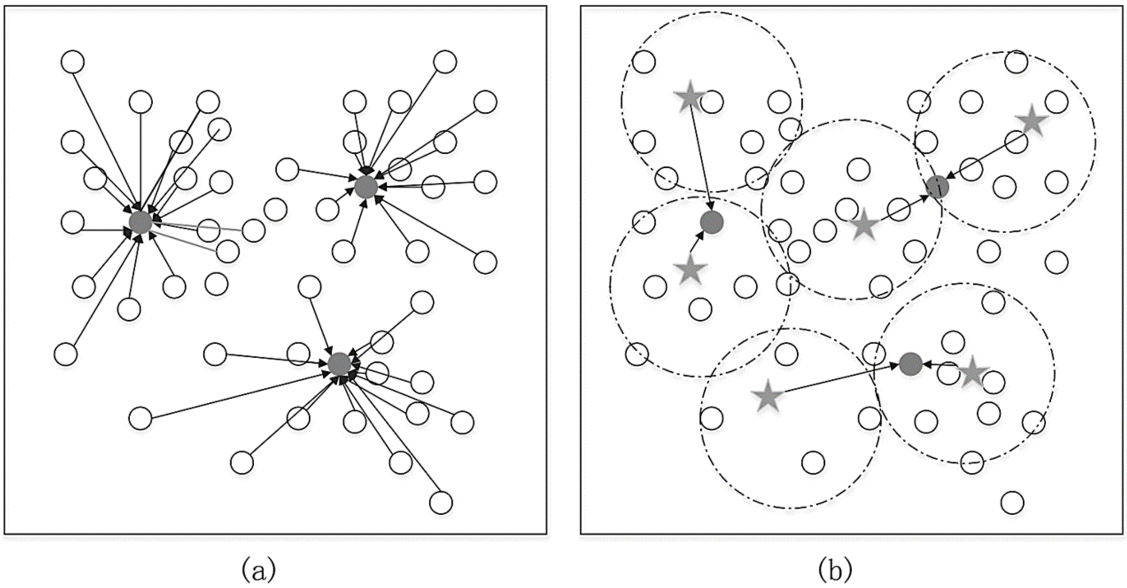


Figure 2.11 – Clustering algorithm comparison: (a) k-Means, (b) Mini-batch k-Means

Source: Xiao *et al.* (2018).

2.2.4.6 Distance and similarity measures

We need an initial concept of similarity or distance between documents to handle the text data mining tasks of clustering, classifying, and retrieving information. The clusters must be composed of points separated by small distances concerning distances between the clusters. However, there are many plausible definitions of distance in this context, and cluster analysis results can significantly depend on the chosen distance measure (MAHARJAN, 2018).

Semantic Textual Similarity (STS) measures the meaning similarity of sentences. First, STS assesses the degree to which two sentences are semantically equivalent. Second, STS assesses pairs of sentences according to their degree of semantic similarity. The task involves producing real-valued similarity scores for sentence pairs. Performance is measured by the Pearson correlation of machine scores with human judgments (CER *et al.*, 2017).

A performance metric is then defined based on the cluster's purity, where purity refers to whether each cluster contains concepts from the same or different categories (WANG *et al.*, 2019).

It is natural to ask what kind of standards we should use to determine the closeness or how to measure the distance (dissimilarity) or similarity between a pair of objects, an object and a cluster, or a pair of clusters. The following section on hierarchical clustering will illustrate linkage metrics for measuring proximity between clusters. Usually, a prototype represents a cluster so that it can be further processed like other objects. Here, we focus on reviewing measure approaches between individuals due to the previous consideration (XU; WUNSCH, 2005).

The most commonly used similarity measure in text data mining and information retrieval is the cosine of the angle between vectors representing the documents, or cosine similarity (CER *et al.*, 2017; MAHARJAN, 2018; XU; WUNSCH, 2005). In addition, sentence embeddings are computed as the sum of individual word embeddings, as shown in the following Equation 2.5:

$$\mathbf{v}(s) = \sum_{w \in s} \mathbf{v}(w) \tag{2.5}$$

Sentences with likely meaning overlap are identified using cosine similarity, as the following Equation 2.6:

$$cos(s_1, s_2) = \frac{\mathbf{V}^T(s_1)\ \mathbf{V}(s_2)}{||\mathbf{V}(s_1)||_2\ ||\mathbf{V}(s_2)||_2} \tag{2.6}$$

where $\mathbf{V}^T(s_1)\ \mathbf{V}(s_2)$ is the product (dot) of the vectors; $||\mathbf{V}(s_1)||_2$ and $||\mathbf{V}(s_2)||_2$ is the length of the two vectors; and $||\mathbf{V}(s_1)||_2\ ||\mathbf{V}(s_2)||_2$ is the cross product of the two vectors.

The word similarity evaluator correlates the distance between word vectors and the semantic similarity perceived by humans. The objective is to measure how well vector representations of words capture the notion of similarity perceived by humans and validate the distributive hypothesis in which the meaning of words is related to the context in which they occur. For the latter, how distributional semantic models simulate similarity is still ambiguous (WANG *et al.*, 2019).

2.2.5 NLP Transformers

Recurrent Neural Networks (RNNs) are a crucial component of modern audio processing systems (SUBAKAN *et al.*, 2021). In RNNs, the words are encoded in vectors, and each new state is based on the previous state, and encoding starts at the final state of the encoder, as shown in Fig. 2.12 - Classical neural networks. Thus, in this figure, the time step only depends on the previous step, as step 7, "good", depends the step 6, "am".

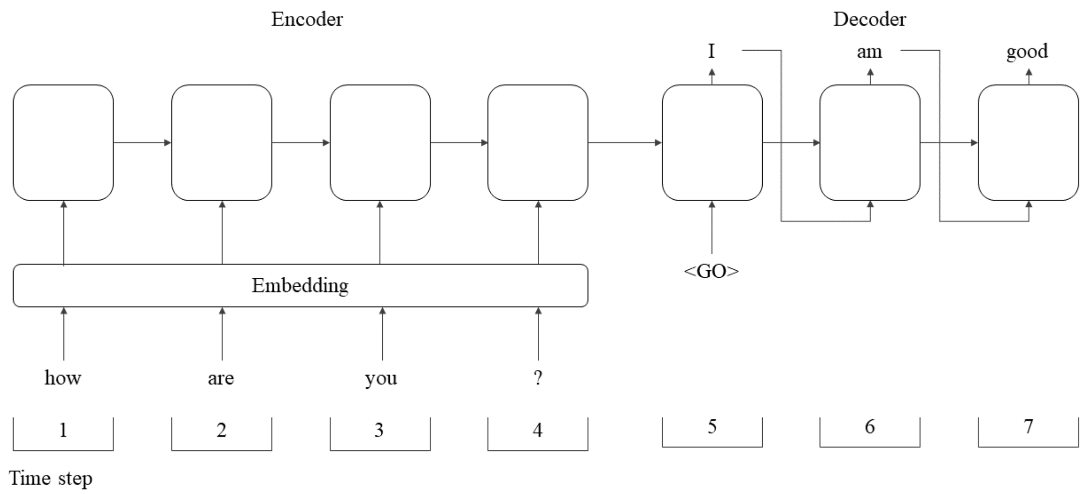


Figure 2.12 – Classical neural networks

Source: Subakan *et al.* (2021).

The practitioners have used RNNs in many different domains of NLP. Especially when coupled with multiplicative gate mechanisms, their recurrent connections are essential to learning long-term dependencies and properly managing speech contexts. However, the intrinsically sequential nature of RNNs impairs an effective parallelization of the computations. This bottleneck is especially noticeable when processing big datasets with long sequences. Alternatively, Transformers avoid this bottleneck altogether by eliminating recurrence and replacing it with a fully attention-based mechanism. Furthermore, by attending to the entire sequence at once, a direct connection can be established between distant elements allowing Transformers to learn long-term dependencies more efficiently. Therefore, Transformers are gaining notable popularity for speech processing and recently showed competitive performance in speech recognition, synthesis, enhancement, diarization, and speaker recognition (SUBAKAN *et al.*, 2021).

In the Encoder-Decoder framework, an encoder reads the input sentence, a sequence of vectors $\mathbf{x} = (x_1, ..., x_{Tn})$, into a vector c. The most common approach is to use an RNN such that Equations 2.7 and 2.8 (BAHDANAU *et al.*, 2014; CHO *et al.*, 2014; SUTSKEVER *et al.*, 2014).

$$h_t = f(x_t, h_{t-1}) \tag{2.7}$$

and

$$r = q(\{h_1, ..., h_{Tx}\}), \tag{2.8}$$

where $h_T \in \mathbb{R}$ is a hidden state at time t, and r is a context vector generated from the sequence of the hidden states. f and q are some nonlinear functions. We can use long short-term memory (LSTM) as f and $q(\{h_1, ..., h_T\}) = h_T$, for instance.

The decoder is often trained to predict the next word y_t, given the context vector c and all previously predicted words $\{y_1, ..., y_{t'-1}\}$. It means, the decoder defines a probability the translation $\mathbf{y}$ by decomposing the joint probability into the ordered conditionals, as Equation

2.9:

$$p(y) = \prod_{t=1}^{T} p(y_t | \{y_1, ..., y_{t-1}\}, r), \tag{2.9}$$

where $\mathbf{y} = \{y_1, ..., y_{T_y}\}$. With an RNN, each conditional probability is modeled as Equation 2.10:

$$p(y_t | \{y_1, ..., y_{t-1}\}, r) = g(y_{t-1}, s_t, r), \tag{2.10}$$

where g is a nonlinear, potentially multi-layered, function that outputs the probability of y_t, and s_t is the hidden state of the RNN. Practitioners can also use other architectures, such as a hybrid of an RNN and a de-convolutional neural network.

A neural machine translation architecture were define following the Equation 2.9, with each conditional probability as Equation 2.11:

$$p(y_i | \{y_1, ..., y_{i-1}\}, \mathbf{x}) = g(y_{i-1}, s_i, r_i), \tag{2.11}$$

where s_i is an RNN hidden state for time i, computed by Equation 2.12:

$$s_i = f(s_{i-1}, y_{i-1}, r_i). \tag{2.12}$$

The context vector r_i is, then computed as a weigthed of these annotations h_i, as Equation 2.13:

$$r_i = \sum_{j=1}^{T_x} \alpha_{ij} h_j. \tag{2.13}$$

The weight α_i of each annotation h_i is computed by Equation 2.14:

$$\alpha_{ij} = \frac{exp(e_{ij})}{\sum_{k}^{T_x} exp(e_{ik})} \tag{2.14}$$

where e_{ij} follow the Equation 2.15:

$$e_{ij} = a(s_{i-1}, h_j) \tag{2.15}$$

is an *alignment model* which scores how well the inputs around position j and the output at position i match. The score is based on the RNN hidden state s_{i-1} (just before emitting y_i, Eq. 2.11) and the j-th annotation h_j of the input sentence (BAHDANAU *et al.*, 2014; CHO *et al.*, 2014; SUTSKEVER *et al.*, 2014), as shown in Fig. 2.13 - RNN graphical illustration: (a) Example, (b) Mathematical.

RNN models generally factor the computation along the symbol positions of the input and output sequences. Aligning the positions to steps in computation time causes a sequence of hidden states h_t, as a function of the previously hidden state h_{t-1} and the input for position t. This inherently sequential nature contains parallelization across training examples, which

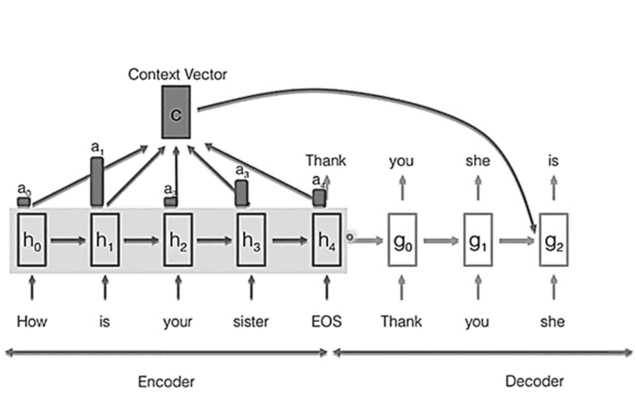


Figure 2.13 – RNN graphical illustration: (a) Example, (b) Mathematical

Source: Bahdanau *et al.* (2014), Cho *et al.* (2014), and Sutskever *et al.* (2014).

becomes crucial at longer sequence lengths as memory constraints limit batching between examples (VASWANI *et al.*, 2017). Although RNNs have been widely used to model contextual representations of textual content, such networks are computationally expensive and fail to capture long-term dependencies in longer written text strings (DAS; VERMA, 2020).

Transformers are a game-changer for Natural Language Understanding (NLU), a subset of Natural Language Processing (NLP), which has become one of the pillars of artificial intelligence in a global digital economy (ROTHMAN, 2021). The Transformer is the first transduction model relying entirely on self-attention to compute its input and output representations without using sequence-aligned RNNs or convolution. At RNNs, the words are analyzed separately instead of a transformer that analyses the complete sentence. A transformer represents an architecture that transforms one sequence into another using two models: encoder and decoder. They are composed of modules that contain feed-forward and attention layers (MISHEV *et al.*, 2020; VASWANI *et al.*, 2017).

This structure of encoder-decoder (RNN) is applied in the most competitive neural sequence transduction models. However, in the transformers encoding process, the encoder maps an input sequence of symbol representations (x_1, ..., x_n) to a sequence of continuous representations z = (z_1, ..., z_n). Given Z, the decoder then generates an output sequence (y_1, ..., y_n) of symbols one element at a time. At each step, the model is autoregressive, consuming the previously generated symbols as further input when generating the next one. The Transformer pursues this general architecture using stacked self-attention and point-wise, fully connected layers for both the encoder and decoder, shown on the left and right sides of Fig. 2.14 - The Transformer: model architecture.

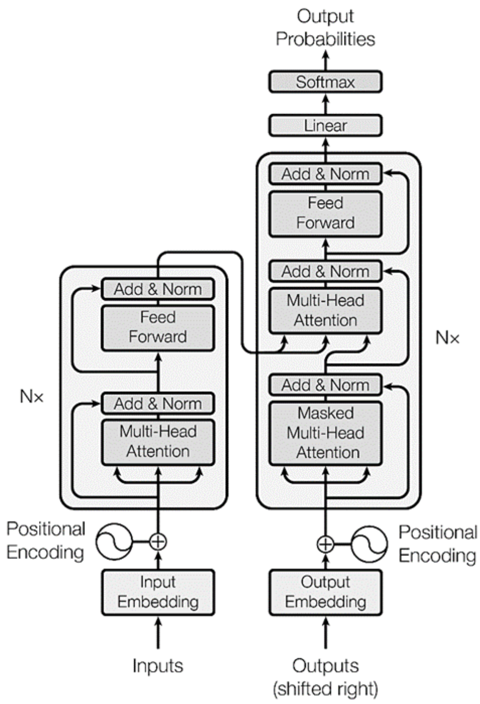


Figure 2.14 – The Transformer: model architecture

Source: Vaswani *et al.* (2017).

2.2.5.1 Attention mask

An attention mask function maps a query and a set of key-value pairs to an output, where the query, keys, values, and output are all vectors. We calculated the output as a weighted sum of the values, where a query compatibility function estimates the weight assigned to each value with the corresponding key (VASWANI *et al.*, 2017).

Transformers architecture works with the entire context in conjunction with two attention mechanisms. The first attention mechanism is the Scale Dot-Product Attention, which means self-attention, or the word's attention to itself. The second attention mechanism is Multi-Head Attention or context-based attention, as shown in Fig. 2.15 - Attention functions: (a) Scaled Dot-Product, (b) Multi-Head. (VASWANI *et al.*, 2017).

In the Scaled Dot-Product Attention Fig. 2.15a the input consists of queries and keys of dimension d_k, and values of dimension d_v. We calculate the dot products of the query with all keys, each divide by $\sqrt{d_k}$, and employ a softmax function to acquire the weights on the values. Indeed, we calculate the attention function on a set of queries simultaneously, packed jointly into a matrix Q. The keys and values are packed into matrices K and V. We calculate the outputs matrix as in Equation 2.16. The main result of the softmax function is how an element is correlated with each other; a graphical result could be a similarity matrix (VASWANI *et al.*, 2017).

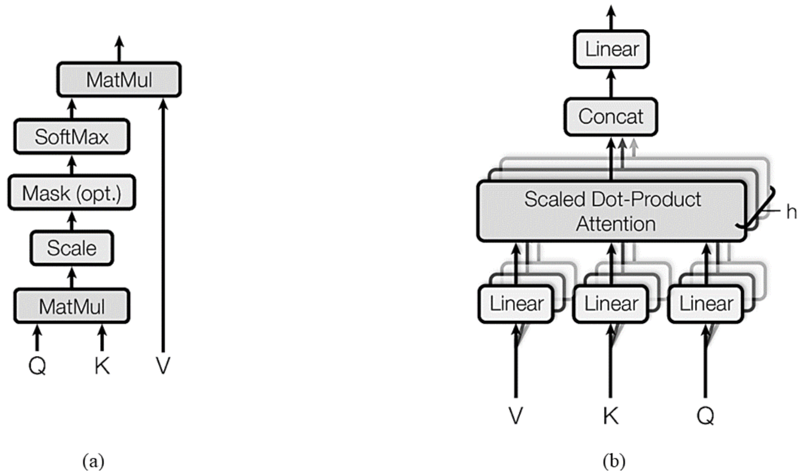


Figure 2.15 – Attention functions: (a) Scaled Dot-Product, (b) Multi-Head.

Source: Vaswani *et al.* (2017).

$$Attention(Q,K,V) = softmax\left(\frac{QK^T}{\sqrt{d_k}}\right)V \tag{2.16}$$

Moreover, in the Multi-Head Attention, rather than performing a single attention function with d_{model}-dimensional keys, values, and queries, we found it beneficial to project the queries, keys, and values h times with different, learned linear projections to d_k, d_k and d_v dimensions, respectively. We process the information from different subspaces in different positions, breaking down the text size. We then perform the attention function in parallel on each of these projected versions of queries, keys, and values, yielding d_v-dimensional output values. Finally, these are concatenated and projected, resulting in the final values, as displayed in Fig. 2.15b (VASWANI *et al.*, 2017). Multi-head attention qualifies the model to together attend to information from diverse representation subspaces at different positions. With a single attention head, averaging inhibits this, as shown in Equation 2.17.

$$MultiHead(Q,K,V) = Concat(head_1, \cdots, head_h)W^O \tag{2.17}$$

where, each of the $head_i$ can be calculated by Equation 2.18.

$$head_i = Attention(QW_i^Q, KW_i^K, VW_i^V) \tag{2.18}$$

where the projections are parameters matrices $W_i^Q \in \mathbb{R}^{d_{model} \times d_k}$, $W_i^K \in \mathbb{R}^{d_{model} \times d_k}$, $W_i^V \in \mathbb{R}^{d_{model} \times d_v}$, and $W^O \in \mathbb{R}^{hd_v \times d_{model}}$, which the model needs to learn. Multi-head attention is vital in getting contextual embeddings when using NLP transformers (MISHEV *et al.*, 2020).

As shown in Fig. 2.14, we have the Add & Norm stage and the Feed Forward stage after the Multi-Head Attention stage. In the Add & Norm stage, the purpose is not to forget the information from the previous step, helping learning during backpropagation. This stage happens five times, two in the input embedding and three and the output embedding (VASWANI *et al.*, 2017).

Moreover, for attention to sub-layers, each layer in our encoder and decoder contains a completely connected Feed-Forward network used for each position separately and identically. As shown in Equation 2.19, these consist of two linear transformations with a ReLU activation in between.

$$FFN(x) = max(0, xW_1 + b_1)W_2 + b_2 \tag{2.19}$$

The Transformers architecture does not use recurrence or convolution neural networks, for the model uses the sequence order. Therefore, we must inject some information about the relative or absolute position of the tokens in the sequence. This information is added in the Positional Encoding stage, after the embedding layer, to create the word's importance.

The Transformers architecture does not use recurrence or convolution neural networks as the model uses the sequence order. Therefore, we must inject some information about the relative or absolute position of the tokens in the sequence. This information is added in the Positional Encoding at the bottoms of the encoder and decoder stages, after the embedding layer, to create the word's importance. Positional encodings have the same d_{model} dimension as embeddings so they can be summed. There are many choices of positional encodings, learned and fixed. Therefore, the best results found were with the Equations 2.20 for even sentences and Equation 2.21 for odd sentences (VASWANI *et al.*, 2017).

$$PE_{(pos,2i)} = sin(pos/10000^{2i/d_{model}}) \tag{2.20}$$

and,

$$PE_{(pos,2i+1)} = cos(pos/10000^{2i/d_{model}}) \tag{2.21}$$

where, *pos* is the index of a word in a sentence and i is the matrix dimension. That is, each dimension of the positional encoding corresponds to a sinusoid. The wavelengths form a geometric progression from 2π to $10000 \times 2\pi$. This function allows the model to learn to attend to relative positions quickly. Such as, for any fixed offset k, PE_{pos+k} can be represented as a linear function of PE_{pos}.

In the Linear stage, the decoder output passes through a dense layer according to the vocabulary size and the application of the softmax function, generating probabilities for each word. Finally, in the last stage, Softmax, Transformers architecture employs learned embeddings to transform the input and output tokens to vectors of the dimension d_{model}. It also utilizes the standard learned linear transformation and softmax function transform the decoder output to predicted next-token probabilities. In Transformers architecture, we share the same weight matrix between the two embedding layers and the pre-softmax linear transformation. Then, we multiply those weights by $\sqrt{d_{model}}$, in the embedding layers. Thus, we present the BERT algorithm in the next subsection 2.2.6 after this elucidation.

2.2.6 Bidirectional encoder representations from transformers - BERT

The latest refinements in NLP have acquired substantial awareness due to their efficiency in language modeling (MISHEV *et al.*, 2020). The large-scale, publicly available pre-trained language models released are ELMo, OpenAI, and Google to compare generative models in NLP (DAS; VERMA, 2020). Recently, deep learning and pre-training models have demonstrated excellent results in several language tasks. Particularly fine-tuning the pre-trained models such as ELMo (Embeddings from Language Models), OpenAI GPT (Generative Pre-Training), GPT-2, and BERT (Bidirectional Encoder Representations from Transformers) has become the best practice for state-of-the-art results (LEE; HSIANG, 2020).

These comprise sentence-level tasks such as natural language inference and paraphrasing, aiming to predict the relationships between sentences by analyzing them holistically. Even NLP comprises token-level tasks such as named entity recognition and question answering, where models are required to produce fine-grained output at the token level (DEVLIN *et al.*, 2018). Two current strategies involve pre-trained language representations for downstream tasks: feature-based and fine-tuning. The feature-based approach, such as ELMo, employs task-specific architectures that contain the pre-trained representations as additional features citepeters2018deep. The fine-tuning approach, such as the Generative Pre-trained Transformer (OpenAI GPT), presents minimal task-specific parameters and is trained on the downstream tasks by fine-tuning all pre-trained parameters (RADFORD *et al.*, 2018). The two approaches share the identical objective function during pre-training, employing unidirectional language models to learn general language representations (DEVLIN *et al.*, 2018). We present these two in more detail following, before presenting the BERT.

ELMo can create context-sensitive embeddings for each word within a sentence, then be provided to downstream tasks. Nonetheless, BERT and GPT employ a fine-tuning approach that can adjust the entire language model to a downstream task, resulting in a task-specific architecture (AMERI *et al.*, 2021). Fig. 2.16 - Pre-training model architectures: (a) Bert, (b) OpenAI GPT, (c) ELMo shows the three strategies involving pre-trained language representations.

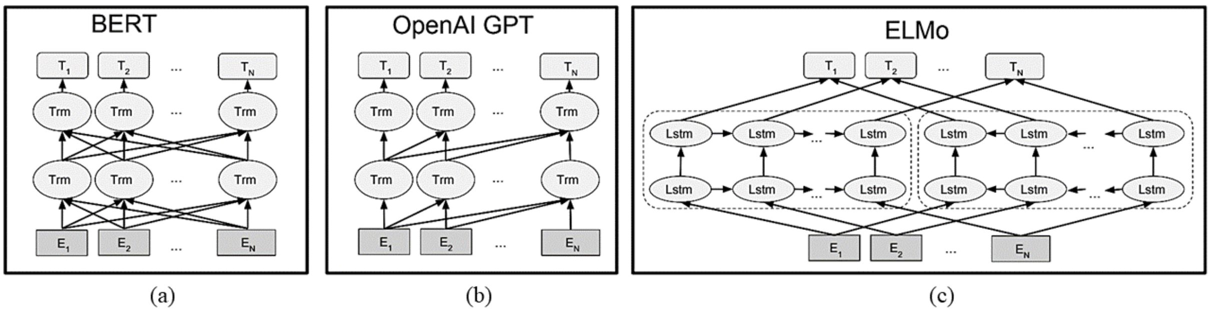


Figure 2.16 – Pre-training model architectures: (a) Bert, (b) OpenAI GPT, (c) ELMo

Source: Devlin *et al.* (2018).

In 2018, a group of researchers at the Allen Institute for Artificial Intelligence developed an advanced word encoder named ELMo (Embeddings from Language Models). Their word embeddings are learned from a deep bidirectional language model (biLM), pre-trained on large corpora of textual data. The attribute which makes ELMo distinct from previous word encoders is that it creates contextual word embeddings. ELMo considers the entire context in which the word is used. Therefore, we can obtain distinct embedding for the same word in a distinct context, a significant improvement from previous encoders, which always produce a static embedding. To tackle out-of-vocabulary (OOV) tokens, ELMo uses character-derived embedding, leveraging the morphological clues of words, thus improving the quality of word representations (PETERS *et al.*, 2018; MISHEV *et al.*, 2020; LIU *et al.*, 2019). ELMo utilizes the concatenation of independently trained left-to-right and right-to-left LSTMs to develop features for downstream tasks, as shown in Fig. 2.16c (DEVLIN *et al.*, 2018).

OpenAI GPT uses a left-to-right architecture, where each token can only serve previous tokens in Transformer's self-attentive layers. Furthermore, we do not have the bidirectional concept. These constraints are sub-optimal for sentence-level tasks and can be especially harmful when involving fine-tuning-based approaches to token-level tasks, such as answering questions. Consequently, it is crucial to incorporate context from both directions (VASWANI *et al.*, 2017; DEVLIN *et al.*, 2018). Fine-tuning directs to model retraining on a task and domain-specific dataset without explicitly changing the architecture to tune the model to the specific data further to be assessed. Nevertheless, fine-tuning such massive transformer models can be computationally intensive (DAS; VERMA, 2020). Fig. 2.16b shows the OpenAI GPT model.

The model BERT ushered in a new era in NLP and overcame the limitation of previous language models, with the state-of-the-art performance achieved in most NLP tasks. Devlin *et al.* (2018) took advantage of transformer architecture to introduce a revolutionary language representation model called BERT (Bidirectional Encoder Representations from Transformers). Fundamentally, BERT integrates the two principles: Transformer and Bidirectional, as the training method is based on language masking. BERT leverages the unsupervised learning approach to pre-train deep bi-directional representations of large corpora of unlabeled text using two new pre-training objectives - masked language model (MLM) and next sentence prediction (NSP) (MISHEV *et al.*, 2020). Fig. 2.16a shows the BERT model.

The advantage of this procedure is that the Transformer encoder in BERT does not know which words will be asked to predict or which have been replaced by random words. It must then hold a contextual distributive representation of each input token. To do so, it builds a bidirectional masked language model, which predicts masked words randomly in the sentence, enriching the contextual information of the words (DEVLIN *et al.*, 2018; MISHEV *et al.*, 2020; PISKORSKI; JACQUET, 2020).

A sequence refers to the input token sequence for the BERT, which can be one or two sentences packed together. BERT's input flexibility can unambiguously represent a single sentence and a couple of sentences in a sequence of tokens, making it possible for BERT to handle multiple downstream tasks.

Every sequence's first token is a unique classification token ([CLS]). The final hidden state corresponding to this token is the aggregate sequence representation for classification tasks. Sentence pairs are packed together into a single sequence. We differentiate the sentences in two ways. First, we separate them with a unique token ([SEP]). Second, we add a learned embedding to every token indicating whether it belongs to Sentence A or B. Equation 2.22 shows these representations (DEVLIN *et al.*, 2018).

$$[CLS] + Sentence_A + [SEP] + Sentence_B + [SEP] \tag{2.22}$$

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

Moreover, Fig. 2.17 - Sequence and sentence size representation illustrates one sentence's tokenization, embedding, and vectorization processing.

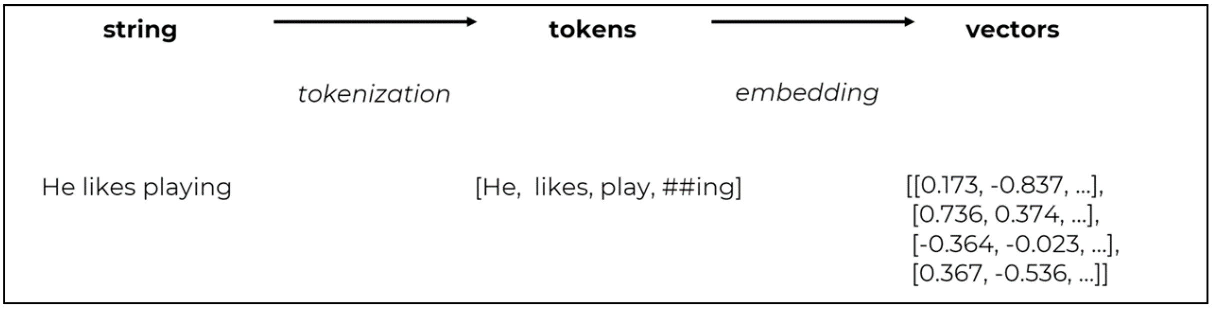


Figure 2.17 – Sequence and sentence size representation

Source: Adapted from Devlin *et al.* (2018).

One of the benefits of employing this architecture is that we can have different sentence sizes. Fig. 2.18 displays a visualization of BERT input representation construction. The input embeddings are the sum of the token embeddings, the segmentation embeddings, and the 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 E $\in \mathbb{R}^H$. Its input representation is constructed for a given token by summing the corresponding token, segment, and position embeddings (DEVLIN *et al.*, 2018).

The BERT architecture follows conventional and autoregressive (AR) language modeling. We maximized the likelihood between the tokens x in a text sequence $x = [x_1, \ldots, x_T]$ in the pre-training process. Allow $\hat{x}$ represent the same text 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 $\hat{x}$ by Equation 2.23 (MISHEV *et al.*, 2020).

$$\max_{\theta} \; log p_\theta(\bar{x}|\hat{x}) \;\approx\; \sum_{t=1}^{T} m_t \; log p_\theta(x_t|\hat{x}) = \sum_{t=1}^{T} m_t \; log \frac{exp(H_\theta(\hat{x})_t^T e(x_t))}{\sum_{x'} exp(H_\theta(\hat{x})_t^T e(x'))} \tag{2.23}$$

where,

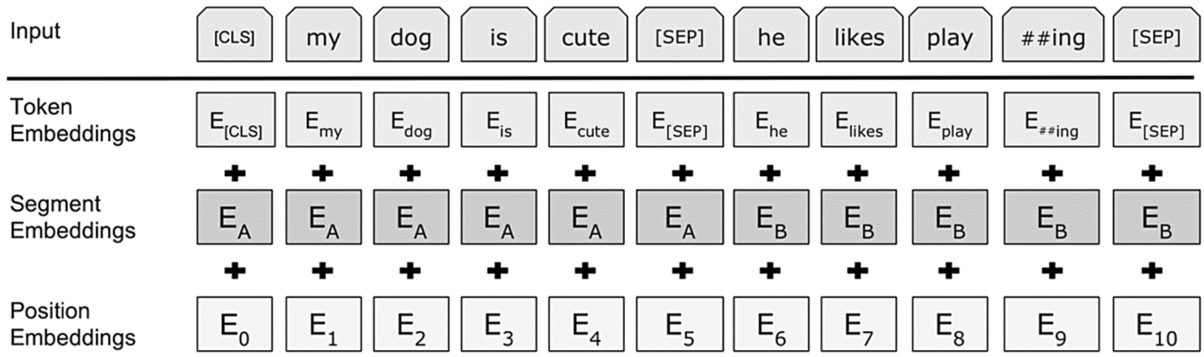


Figure 2.18 – BERT input representation

Source: Devlin *et al.* (2018).

- x is a text sequence $x = [x_1, \ldots, x_T]$;
- $\hat{x}$ the same text sequence with masked tokens;
- $\bar{x}$ is an array of masked tokens;
- $e(x)'$ represents the embedding of token x;
- $m_t = 1$, if x_t token of the text sequence x is masked;
- H_θ is a Transformer that transforms each token of text sequence into a hidden vector;
- p_θ is the approximation of the joint conditional probability $p(\bar{x}, \hat{x})$.

BERT takes that all masked tokens $\bar{x}$ are mutually independent, which is the primary rationale behind the approximation of the joint conditional probability $p(\hat{x}|\bar{x})$ in Equation 2.23. Another benefit that distinguishes BERT from previous AR methods is the capacity to improve the context information $H_\theta(x)_t$ by accessing the tokens placed on the left and the right side of token t. BERT has two versions: BERT-base, with 12 encoder layers, hidden size of 768, 12 multi-headed attention heads, and 110M parameters in total; and BERT-large, with 24 encoder layers, 1024 hidden size, 16 multi-head attention heads, and 340M parameters. Both models were trained on English Wikipedia, and BookCorpus (DEVLIN *et al.*, 2018; MISHEV *et al.*, 2020).

Since 2018, some versions of BERT have been developed like FinBERT, SciBERT, BioBERT, AlBERT, TweetBERT, RoBERTa, DilstilBERT, XLM-RoBERTa, and BART. Next subsection shows the DiltilBERT.

2.2.7 DistilBERT

DiltilBERT is based on a methodology that decreases the BERT's size model by 40% while retaining 97% of its language understanding capabilities and 60% faster. The technique that compresses the original model is known as knowledge distillation. The compact (student) model is trained to reproduce the full output distribution of the more extensive (teacher) model or ensemble models. Instead of cross-entropy training on hard targets (one-hot coding of classes), the student gains knowledge based on a loss of distillation about the teacher's soft target probabilities. We calculate the distillation loss L_{ce} using Equation 2.24 (SANH *et al.*, 2019; MISHEV *et al.*, 2020).

$$L_{ce} = \sum_{i} t_i \times log(s_i) \tag{2.24}$$

where t_i and s_i are the teacher's and student's estimated probabilities, respectively, this objective results in a richer training signal since soft-target probabilities enforce stricter constraints than a single hard-target.

2.2.8 Sentence-BERT

A disadvantage of the BERT network structure is that no independent sentence embeddings are computed, making it challenging to derive them from BERT. To avoid this boundary, researchers passed single sentences through BERT and then derived a fixed-sized vector by either averaging the outputs (similar to average word embeddings) or by using the output of the unique CLS token (REIMERS; GUREVYCH, 2019).

Sentence-BERT (SBERT) is a modification of the pre-trained BERT network that uses siamese and triplet network structures to derive semantically meaningful sentence embeddings. SBERT can be compared by using cosine similarity. The quality evaluation of SBERT on various standard benchmarks notably improves over state-of-the-art sentence embedding methods (REIMERS; GUREVYCH, 2019).

The structures and objective functions of SBERT are as follows. Fig. 2.19 - SBERT architecture with classification objective function shows the first, the Classification Objective Function, where we concatenate the sentence embeddings u and v with the element-wise difference $|u$ - $v|$ and multiply it with the trainable weight $W_t \in \mathbb{R}^{3n \times m}$, as Equation 2.25:

$$o = softmax(W_t(u, v, |u - v|)) \tag{2.25}$$

where n is the dimension of the sentence embeddings and m the number of labels. We optimize cross-entropy loss.

Fig. 2.20 - SBERT architecture at inference - computing STS scores shows the second structure, Regression Objective Function, where we calculate the cosine similarity between the two sentence embeddings u and v and use the mean squared-error loss as the objective function.

Finally, the third structure is a Triplet Objective Function. Given an anchor sentence a, a positive sentence p, and a negative sentence n, triplet loss adjusts the network such that the distance between a and p is smaller than between a and n. Then, mathematically, we minimize the following loss function as Equation 2.26:

$$max(||s_a - s_p|| - ||s_a - s_n|| + \in, 0) \tag{2.26}$$

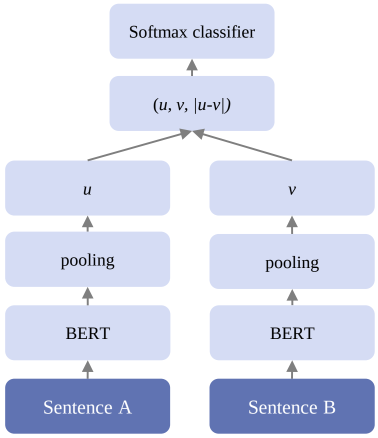


Figure 2.19 – SBERT architecture with classification objective function

Source: Reimers e Gurevych (2019).

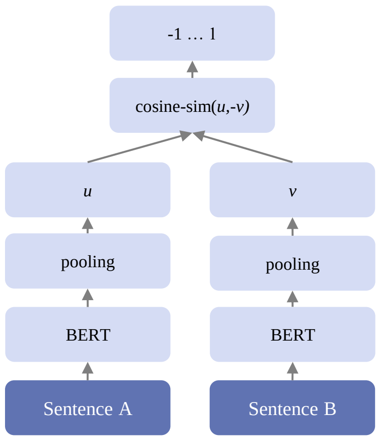


Figure 2.20 – SBERT architecture at inference - computing STS scores

Source: Reimers e Gurevych (2019).

where s_x the sentence embedding for $a/n/p$, $||\cdot||$ a distance metric and margin $\in$. Margin $\in$ ensures that $a/n/p$, is at least $\in$ closer to s_a than s_n. As a metric, we apply Euclidean distance, and we set $\in = 1$ (REIMERS; GUREVYCH, 2019).

There are many Sentence-BERT (SBERT) pre-trained BERT network models available, which have been extensively evaluated for their quality of embedded sentences (Performance Sentence Embeddings) and embedded search queries & paragraphs (Performance Semantic Search) (REIMERS; GUREVYCH, 2019). The models are available at www.sbert.net[2].

Hence, we fulfill the characterization of the NLP theoretical framework, and in the following Section 2.3, we present the DEMATEL multicriteria decision method.

2 https://www.sbert.net/docs/pretrained_models.html

2.3 Decision-Making Trial and Evaluation Laboratory (DEMATEL)

This section presents the traditional formulations of the DEMATEL MCDM method explored in this thesis.

The combination of MCDM techniques has a massive application (SOUZA *et al.*, 2021b; SOUZA *et al.*, 2022), and combining algorithms with MCDM techniques already came into use in 2010, with MCDM techniques used to select the best algorithm set method (KOU *et al.*, 2014; ROKACH, 2010; SOUZA *et al.*, 2021a). The evaluation of clustering algorithms is inherently challenging because of the lack of objective measures. Similarly, since the evaluation of clustering algorithms involves multiple criteria, it can be modeled as an MCDM problem (KOU *et al.*, 2014).

The Geneva Research Centre of the Battelle Memorial Institute created the early 70s Decision-making trial and evaluation laboratory (DEMATEL) technique to visualize the structure of complicated causal relationships through matrixes or digraphs (GABUS; FONTELA, 1972; SI *et al.*, 2018). The practitioners employ DEMATEL to display the interrelations among criteria and discover the principal criteria representing the effectiveness of factors/aspects (LEE *et al.*, 2013). Researchers have applied DEMATEL in many situations, such as marketing strategies, control systems, safety problems (LIOU *et al.*, 2007; LIOU *et al.*, 2008), development of global managers' competencies, group decision-making (LIN; WU, 2008; WU *et al.*, 2010), identify the key success factors in service quality (SHIEH *et al.*, 2010) green supply chain management practices (LIN, 2013), and project portfolio selection (SOUZA *et al.*, 2020).

DEMATEL is built on graph theory, making it possible to analyze and solve problems using visualization. This structural modeling approach uses a directed graph, a causal effect diagram, to illustrate interdependence relationships and values of significant effects between factors. A visual relationship of levels between system factors divides all elements into causal and affected groups. Furthermore, this can give researchers a better comprehension of the structural relationship between system elements and discover ways to solve complex system problems (LIN, 2013; GABUS; FONTELA, 1972).

Fig. 2.21 shows the DEMATEL number of articles by approach type (SI *et al.*, 2018). Founded on the DEMATEL methods adopted, the Author grouped the selected publications into five categories: those that combine network analytical process (ANP) and DEMATEL, those that use the classic DEMATEL, those that use the fuzzy DEMATEL, those that use the gray DEMATEL and those based on other DEMATEL methods.

Accordingly, the classic DEMATEL spread broadly by the researchers until 2018 in at least 105 (30.3%) articles (SI *et al.*, 2018). Nonetheless, ANP and DEMATEL were present in 154 (44.5%) of the articles and Fuzzy DEMATEL in 63 (18.2%). Yang et al. employed

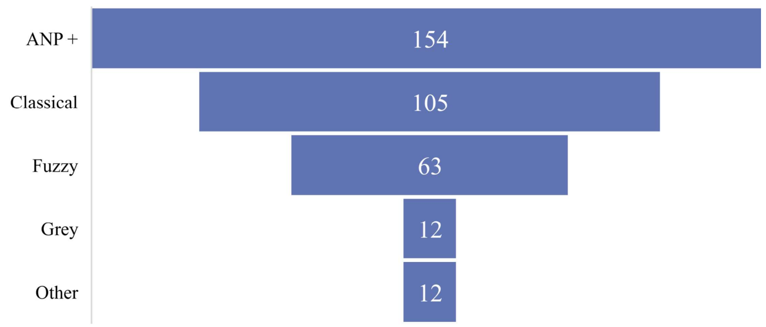


Figure 2.21 – DEMATEL number of articles by approach type

Source: Si *et al.* (2018).

DEMATEL not just to detect complex relationships and build an impact-relation map (IRM) of the criteria but even to acquire the influence levels of each element over others (YANG *et al.*, 2008). They then adopted these influence level values as the basis of the normalization supermatrix for determining ANP weights to get relative importance. As a result, the ANP, the general analytic hierarchy (AHP), has been applied successfully in considerable practical decision-making problems (LEE *et al.*, 2013). Wu e Lee (2007) presented a proper method combining fuzzy logic and the DEMATEL to part required competencies for better promoting global managers' competency development, which applies the vagueness of human judgments.

Table 2.20 shows the advantages and disadvantages of using the classical DEMATEL. However, we can surpass these disadvantages by integrating DEMATEL with other MCDM methods.

Table 2.20 – Advantages and disadvantages of classical DEMATEL

Advantages	Disadvantages
It points out cause-effect relationships between criteria/projects by analyzing mutual influences (direct and indirect effects).	The criteria or projects are solely analyzed by their interdependence.
The interrelationship can be visually analyzed via IRM.	The judgments from different experts are not weighted when aggregating individual assessments into group assessments.
It can be used to rank the criteria/projects and evaluate their criticality. The criteria/projects are evaluated by their interactions and dependencies. Unlike other methods that assume dependences with equal weights (such as ANP), in DEMATEL, these dependencies are weighted.	It cannot take into account the aspiration level of alternatives (such as GRA and VIKOR) nor obtain partial ranking orders of alternatives (such as ELECTRE approaches).

Source: Si *et al.* (2018), Souza *et al.* (2020).

We convert the relationships between cause and effect factors in DEMATEL. Next subsection presents the steps of DEMATEL method.

2.3.1 DEMATEL Steps

First, suppose a system contains a set of elements $B = \{b_1, b_2, \ldots, b_n\}$, then we choose to model mathematical relationships for these specific pair relationships. Thus, we have summarized the significant steps of the DEMATEL method into six steps (GABUS; FONTELA, 1972; SI *et al.*, 2018; SHIEH *et al.*, 2010; LEE *et al.*, 2013; LIN, 2013).

- ***Step 1:*** Develop the initial group direct-influence matrix B.

In a system, to evaluate the connection between n clusters $G = \{g_1, g_2, \ldots, g_n\}$, assume that m experts in a decision group $E = \{E_1, E_2, \ldots, E_m\}$ are asked to indicate the direct influence that cluster g_i has on cluster g_j, using an integer scale. The scales 0, 1, 2, 3, and 4 represent the range from "no influence (0)", "low influence (1)", "medium influence (2)", "high influence (3)" to "very high influence (4)", respectively. The notation of g_{ij} indicates the degree to which the respondent believes cluster g_i affects cluster g_j.

Then, the individual direct-influence matrix $B_m = \left[b_{ij}^m\right]_{n \times n}$, where $n = g_n$, see Equation 2.27, provided by the mth expert can be formed, where all principal diagonal elements are equal to zero and c_{ij}^m represents the judgment of decision maker E_k, as shown in Equation 2.27.

$$b_m = [b_{ij}^m]_{nxn} = \begin{bmatrix} 0 & b_{12}^m & \ldots & b_{1j}^m \\ b_{21}^m & 0 & \ldots & b_{2j}^m \\ \vdots & \vdots & \ddots & \vdots \\ b_{i1}^m & b_{i2}^m & \ldots & 0 \end{bmatrix} \tag{2.27}$$

By aggregating the m experts' opinions, the group direct-influence matrix $B_m = \left[b_{ij}\right]_{n \times n}$ can be obtained by the Equations 2.28 and 2.29:

$$b_{ij} = \frac{1}{m}\sum_{p=1}^{m} b_{ij}^p, \quad i, j \in \{1, 2, \ldots, n\} \tag{2.28}$$

where,

$$B = [b_{ij}]_{nxn} = \begin{bmatrix} 0 & \frac{1}{m}\sum_{p=1}^{m} b_{12}^p & \ldots & \frac{1}{m}\sum_{p=1}^{m} b_{1j}^p \\ \frac{1}{m}\sum_{p=1}^{m} b_{21}^p & 0 & \ldots & \frac{1}{m}\sum_{p=1}^{m} b_{2j}^p \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{m}\sum_{p=1}^{m} b_{i1}^p & \frac{1}{m}\sum_{p=1}^{m} b_{i2}^p & \ldots & 0 \end{bmatrix} \tag{2.29}$$

The initial group direct-influence matrix $B_m = \left[b_{ij}\right]_{n \times n}$ is also named the average matrix. The matrix B illustrates the initial direct effects a factor exerts and receives from other factors (LEE *et al.*, 2013).

- ***Step 2:*** Calculate the normalized initial direct-relation matrix.

After we obtained the group direct-influence matrix B, the normalized direct-influence matrix $X = \left[x_{ij}\right]_{n\times n}$ can be achieved by the Equations 2.30 and 2.31.

$$X = \frac{B}{s}, \tag{2.30}$$

where,

$$s = max\left(\max_{1\leq i\leq n}\sum_{j=1}^{n} b_{ij}, \max_{1\leq i\leq n}\sum_{i=1}^{n} b_{ij}\right) \tag{2.31}$$

where, all elements in the matrix X are complying with $0 \leq x_{ij} < 1, 0 \leq \sum_{j=1}^{n} x_{ij} \leq 1$, and let at least one i such that $\sum_{j=1}^{n} b_{ij} \leq$ s.

- ***Step 3:*** Construct the total-influence matrix T.

Using the normalized direct-influence matrix X, the total-influence matrix $T = \left[t_{ij}\right]_{n\times n}$ is then computed by summing the direct and indirect effects by Equation 2.32.

$$T = X(I - X)^{-1}, \tag{2.32}$$

where, I is denoted as an identity matrix and X the normalized direct-influence matrix.

- ***Step 4:*** Compute dispatcher group and receiver group.

For the total-relation matrix T (Equation 2.33), calculate the sum of columns R (Equation 2.34) and rows D (Equation 2.35) for the elements:

$$T = [t_{ij}]_{n\times n},\ (i, j = 1, 2, \ldots, n) \tag{2.33}$$

and,

$$R = [r_i]_{nx1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{nx1},\quad j \in \{1, 2, \ldots, n\} \tag{2.34}$$

and,

$$D = [d_j]_{1xn} = \left[\sum_{i=1}^{n} t_{ij}\right]^{T}_{1xn},\quad i \in \{1, 2, \ldots, n\} \tag{2.35}$$

where, r_i is the ith row sum in the matrix T and displays the sum of direct and indirect effects dispatching from factor F_i to the other factors. Similarly, d_j is the jth column sum in the matrix T and depicts the sum of direct and indirect effects that factors is receiving from the other factors.

- ***Step 5:*** Create an Influential Relation Map (IRM).

In short, we are producing a causal diagram. The sum of the rows and the columns are indicated separately as vectors D and R within the total relation matrix M. We can obtain a causal and effect plot by mapping the dataset of ($R + D$; $R - D$). The horizontal axis vector ($R + D$) called “Prominence” is made by adding D to R, demonstrating the criterion’s importance. Similarly, the vertical axis ($R - D$) called “Relationship” is constructed by subtracting D from R, which can group criteria into a group of causes. Alternatively, if the ($R - D$) is negative, the criterion is grouped into the effect group, as shown in Figure 2.22 - DEMATEL four-quadrant Influential Relation Map (IRM).

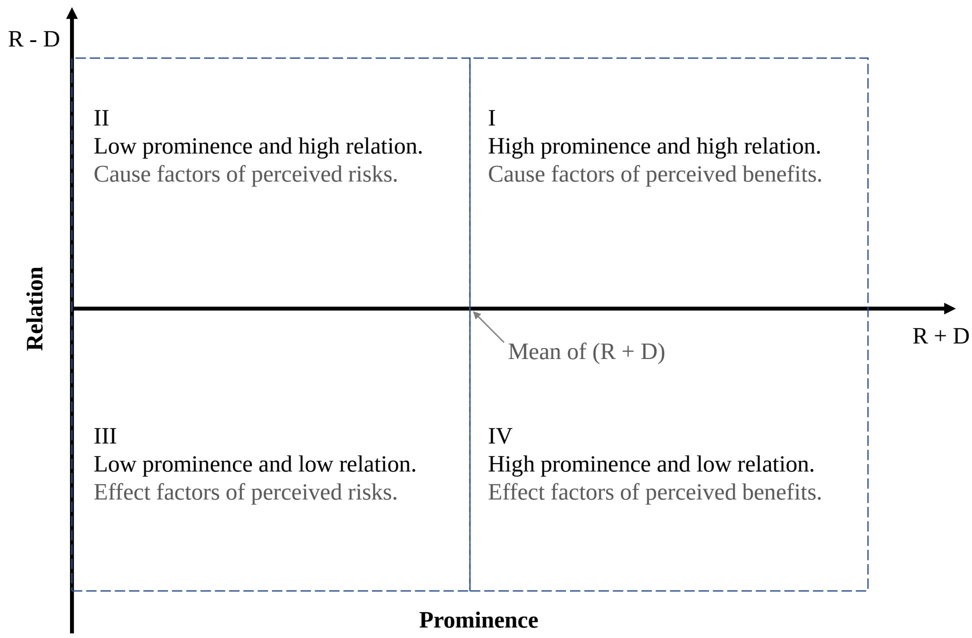


Figure 2.22 – DEMATEL four-quadrant Influential Relation Map (IRM)

Source: Lee *et al.* (2013), and Shieh *et al.* (2010).

When $j = i$, the sum ($r_i + d_j$) shows the total effects given and received by factor i. That is, ($r_i + d_j$) denotes the degree of importance factor i plays in the system. On the contrary, the difference ($r_i - d_j$) indicates the net effect that factor i contributes to the system. If ($r_i - d_j$) is positive, factor i is a net cause, while factor i is a net receiver or result if ($r_i - d_j$) is negative.

Notice that classical DEMATEL does not rank the alternatives according to their influence over each other. Instead, it ends after creating the IRM and analyzing the cause-effect between alternatives. Likewise, the third type of DEMATEL defines criteria weights by investigating the interrelationships and impact levels of the criteria. Following, we present the optional steps of the third type of DEMATEL.

- ***Step 6a***: Set a threshold value to draw the IRM.

Furthermore, in the above, the IRM is constructed based on the T matrix information to explain the factors’ structural relationships. However, in some situations, IRM will be too complex to show valuable information for decision-making if we consider all relationships. Therefore, a threshold value of φ is defined to filter out insignificant effects. That is, only the element of the matrix T, whose level of influence is greater than the value of φ, is selected and converted to an IRM. If the threshold value φ is too low, too many factors are included, and the IRM is too complex to understand. Nevertheless, some critical factors can be excluded if the threshold value is too high (SI *et al.*, 2018).

Since matrix T provides information on how one factor affects another, a decision-maker must set up a threshold value to filter out some negligible effects. Only the effects more significant than the threshold value would be chosen and shown in the digraph. We develop the digraph by mapping the dataset of $(r + d, r - d)$ (SHIEH *et al.*, 2010).

In the literature, the researchers usually defined threshold value φ through discussions, the brainstorming technique, the maximum mean deentropy (MMDE), the mean of all elements of the matrix T, or the maximum value of the diagonal elements of the matrix T (SI *et al.*, 2018).

- ***Step 6b**:* Obtain the inner dependence matrix T'

The inner dependency matrix T' is derived based on the threshold value φ and only factors whose effects on the matrix T are greater than φ are shown in the matrix T' (LIN; SUN, 2010; SI *et al.*, 2018).

- ***Step 6c**:* Split the IRM into four quadrants.

Once an IRM is acquired, we classified the factors into four quadrants according to their locations in the diagram, as shown in Figure 2.22. We split the IRM into four quadrants, I to IV, by calculating the mean of $(R + D)$.

The factors in the first quadrant (I) are identified as central or intertwined givers, as they hold high prominence and relationship. Quadrant II shows the factors identified as driving factors or autonomous givers because they have low prominence but high relation. Further, quadrant III shows the factors with low prominence and relation and relatively disconnected from the system (named independent factors or autonomous receivers). Finally, quadrant IV shows the factors with high prominence but low relation (named impact factors or intertwined receivers), which are affected by other factors and cannot be directly improved. From Figure 2.22, practitioners can visually detect the complex causal relationships between factors and highlight even more valuable information for decision-making (SI *et al.*, 2018; YAZDI *et al.*, 2020).

3 METHODOLOGY

In this chapter are the significant developments of this research, in addition to theories strictly linked to the developments and fundamental assumptions of developments to support the first-level ones. Moreover, this chapter defines the methodology applied in the research for proposing and grouping a base of indicators for contracting self-employed professionals in software development in the context of the Gig Economy, discussing the necessary steps for constructing the novel proposed approach.

The research steps are summarized by following the research objectives, as shown in Subsection 1.2.2 - Intermediate objectives, to create a table of relationships between the general objective, main steps, research strategy, methods, tools, and outcomes, as shown in Table 3.1 - Relationship between the general objective, methods, tools, and outcomes.

Moreover, Fig. 3.1 - Research framework of the *second* and *third stages* methodology presents a detailed explanation of the thesis to illustrate the detailed steps taken. In this figure, we display only the *second* and *third stages*; the *first stage* was the SLR. Hence, the *first stage* comprises the first and second main steps of Table 3.1 - Relationship between the general objective, methods, tools, and outcomes, which has already been presented in Section 2.1 - SLR methodology and findings.

Hence, we split this chapter into two sections:

- Section 3.1 - NLP hierarchical structure 2D of the Criteria clusters presents how we group the criteria only using the NLP and $k$means. The *second stage* of the methodology.
- Section 3.2 - 3D hierarchical structure of the Criteria clusters. The *third stage* of the methodology.

Further, we split the Section 3.2 into three subsections:

- Subsection 3.2.1 - DEMATEL Method, showing the classical method used and how we get the 1st and 2nd axis of the proposed method.
- Subsection 3.2.2 - Semantic text similarity (STS), presenting how we create the 3rd axis to make the 3D hierarchical cluster.
- Subsection 3.2.3 - The proposed method, which places together all the steps taken.

After fulfilling the steps of the *first stage* in the Section 2.1 - SLR methodology and findings, we are ready to move on to the second stage, as shown in the following Section 3.1.

Table 3.1 – Relationship between the general objective, methods, tools, and outcomes

***General objective**: to develop clusters of criteria for hiring self-employed professionals in the Global Software Development (GSD) or Gig Economy (GE) context.*

Main steps	**Research Strategy and Method**	**Tools and Software**	**Outcomes**
Identify and record the attributes** related to the GSD or GE context.	SLR strategy	Excel, Scopus® and WoS® database.	List of attributes
Transform the attributes in criteria, convert them into indicators, and report SLR findings.		Excel, RStudio, and Minitab®.	Criteria list and SLR report.
Cluster the criteria list.	Modelling method	NLP, SBERT, and *k*means algorithms in Python framework.	List of proposed grouped criteria
Create a fast and initial hierarchical structure by clustering the criteria clusters formed.			An initial hierarchical structure.
Apply the DEMATEL MCDM (Get 1st and 2nd axis).		Excel.	Influential Relation Map (IRM).
Obtain the direct influence of DEMATEL.		Interviews with practitioners and Excel.	The initial direct-influence matrix of DEMATEL.
Create the 3rd axis of the 3D* systematic approach.		NLP/SBERT/Pytorch algorithm in Python framework.	A quantitative semantic textual similarity (STS) of the cluster groups.
Integrate NLP, *k*means, DEMATEL, and Ward linkage hierarchical algorithm into a novel approach.		Python framework and Minitab®.	3D hierarchical structure graph for contracting professionals in GE/GSD.

**The 3D hierarchical structure comprises two axes from DEMATEL and the third from NLP/STS.*
***Attributes: issues, gaps, challenges, barriers, best practices, success factors, risks, and threats for contracting professionals in GE/GSD.*

Source: Author.

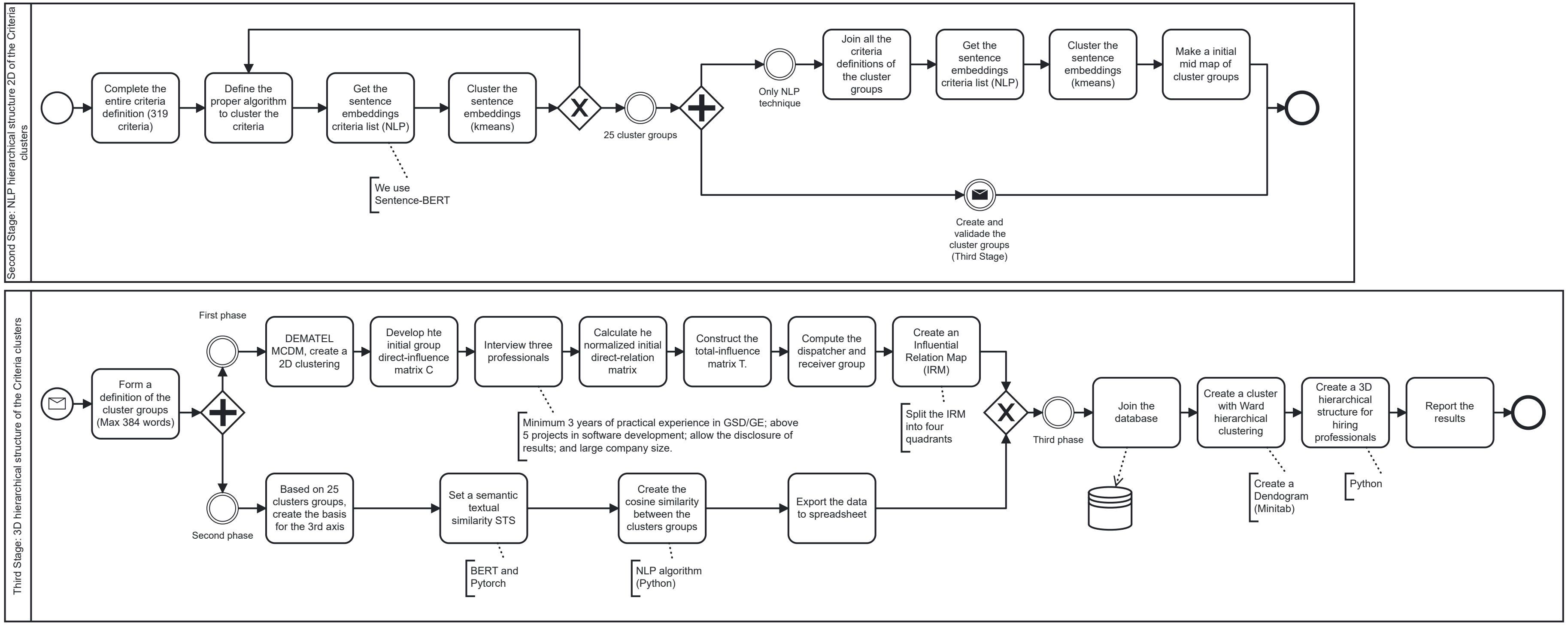


Figure 3.1 – Research framework of the *second* and *third stages* methodology

Source: authors.

3.1 NLP hierarchical structure 2D of the Criteria clusters

The methodology of the *second stage*, as shown in Fig. 3.1, starts with the review of the complete definitions of the 319 criteria ($c_1, c_2, \ldots, c_{319}$). We revised these definitions (See Tables 2.7 until 2.16 - Criteria list for contracting professionals in GSD - 10/10) and prepared them in a spreadsheet to be used in the Python framework. Then, through Natural Language Processing (NLP) techniques, we define the proper algorithms to group the criteria.

Consequently, to get the sentence embeddings of criteria list definitions, we define the SBERT algorithm than BERT because the average results are better for sentences. Thus, we used the Sentence-BERT (SBERT) pre-trained BERT network in this work (See Subsection 2.2.8). Moreover, we choose the model name "all-mpnet-base-v2" due to its high average performance[1]. 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.

Clustering describes a Machine Learning approach in which we systematically group the objects into several categorical groups based on similarity; these groups are called clusters. The ability to identify previously unknown groups and patterns in existing data through clustering makes it a valuable tool in many fields of application and for many research directions (KAYA; SCHOOP, 2021; GAN *et al.*, 2020; FRADES; MATTHIESEN, 2010). The various clustering approaches have different advantages and disadvantages and, therefore, should be carefully evaluated concerning application and success, especially for high-dimensional data (KAYA; SCHOOP, 2021).

The clustering techniques in the current investigation context need to be useful for textual data. The *k*means clustering technique has often been used in various real-world scenarios (AGNIHOTRI *et al.*, 2014; KAYA; SCHOOP, 2021), as shown in Subsections 2.2.4.4 and 2.2.4.5. Hence, considering the described cosine similarity as the Equation 2.6 in Subsection 2.2.4.6, *k*-Means clustering can be computationally efficient, particularly for sparse high-dimensional data vectors resulting from the conversion of natural language and documents (JUN *et al.*, 2014; RAVINDRAN; THANAMANI, 2015).

The primary concept of *k*means is to split the underlying data objects into a predefined number of clusters, where we assign individual instances to the cluster with the closest cluster center. Then, the cluster center is iteratively determined until no cluster center is found that has a smaller overall distance to cluster instances than the current center and therefore achieves its convergence criterion (KHAN; AHMAD, 2004; KAYA; SCHOOP, 2021).

The Pseudocode 2 shows the *k*means method (MITTAL *et al.*, 2022).

Consequently, using the sentence embedding obtained from SBERT, we apply the *k*means

[1] https://www.sbert.net/docs/pretrained_models.html

Algorithm 2 *k*means pseudocode

1: **Input**: The criteria $(c_1, c_2, \ldots, c_{319})$ obtained in the SLR.
2: **Output**: The clustered criteria $(g_0, g_1, \ldots, g_n)$.
3: Decide and insert the number of clusters k.
4: Randomly select distinct data points as initial cluster centroids;
5: **while** Clustering condition is not satisfied, or centroids do not change **do**
6: Compute the objective function, defined in eq. 2.3;
7: Assign each data point to the closest cluster;
8: Update the cluster centroids;
9: **end while**

Source: Adapted from (MITTAL *et al.*, 2022).

clustering approach in a Python framework in this work. For that, we require first to decide the number of criteria clusters $G = g_0, g_1, \ldots, g_n$. Firstly, instead of choosing only one number of clusters, we delimited $16 \leq g_n \leq 25$ clusters. Thus, we executed the algorithm ten times until we had a matching cluster. After that, we analyze the most meaningful cluster. Moreover, after achieving the proper criteria clusters, we build the word cloud for each cluster $g_0, g_1, \ldots, g_n$ to help create cluster names.

At this point, we have the cluster formed, and the question remains concerning how to present the data quickly. Following Fig. 3.1, we have two options going to *third stage methodology* or representing the cluster groups in an initial and fast way using only NLP techniques.

Therefore, by applying only the NLP technique, we create a fast and initial hierarchical structure cluster groups $NG = ng_1, ng_2, \ldots, ng_n$ of the criteria clusters $g_0, g_1, \ldots, g_n$. To do that, we repeat the algorithm NLP/SBERT, and *k*means to cluster the clusters formed and create cluster groups of the clusters. However, in this case, in a spreadsheet, we only join all the criteria definitions in the same cluster group and create an initial cluster group definition. Then, we put together the g_n clusters in a spreadsheet, got the sentence embeddings of this initial cluster group's definition, and repeated the same clustering algorithm. Again, instead of choosing only one number of clusters, we delimited $4 \leq ng_n \leq 6$ clusters groups. Thus, we executed the algorithm three times (4, 5, and 6 groups) until we had the most meaningful cluster groups. Also, we created a cluster groups word cloud to support creating cluster group names. Finally, to present the initial hierarchical structure, we choose and create an interactive mind map to show the clustering results and criteria.

In the next Section 3.2, we show how we cluster, test the criteria innovatively and responsively and create the relationships between the criteria clusters.

3.2 3D hierarchical structure of the Criteria clusters

The *third stage* methodology, as shown in Fig. 3.1, starts with adjusting the cluster group definitions to facilitate interviews with practitioners and to create STS (Semantic Text Similarity). Thus, we exclusively use the criteria definitions of the cluster groups and make a 384-words summary. By following the Fig. 3.1 - Research framework of the *second* and *third stages* methodology, this *third stage* have three phases:

1. Apply the DEMATEL MCDM (Get 1^{st} and 2^{nd} axis) to get the IRM map and do the interviews with three practitioners (Subsection 3.2.1);
2. Create the 3^{rd} axis of the 3D systematic approach by using the STS (Subsection 3.2.2);
3. With IRM map and STS create a 3D hierarchical structure of the clusters (Ward linkage hierarchical clustering + 3d Python) (Subsection 3.2.3).

The following subsections show these phases.

3.2.1 DEMATEL Method

This subsection shows the classical steps of the DEMATEL MCDM taken. The use of DEMATEL is justified because it allows it to be worked in a spreadsheet, facilitating its use and being an advantage of its choice. Furthermore, the primary justification was due to its characteristic of building relationships, or a causal dependency, between the criteria and the influence map chart. The DEMATEL approach assesses the criteria cluster groups according to their global importance and influence on each other, assuming the uncertainty related to the imprecision of the data. Consequently, DEMATEL can effortlessly map the interrelationships between the recognized factors into an understandable structural model of the system under analysis (SI *et al.*, 2018; YAZDI *et al.*, 2020).

First, within the MCDM problem steps, suppose a system composed of cluster groups $G = \{g_1, g_2, \ldots, g_n\}$ corresponds to each group of criteria. Fig. 3.2 shows the structure of the problem, which starts from the goal of this work, and in sequence, the data acquisition (the criteria obtained by SLR). Further, the relative importance of the cluster groups will be obtained from practitioners' interviews. Finally, from the synthesis of data obtained from the judgments, we calculate the priority of each alternative concerning the main focus. Lastly, the sensitivity analysis identifies how consistent the classification system is by examining the impact of the cluster groups.

We apply the following adapted steps as shown in Subsection 2.3.1.

- ***Step 1:*** Develop the initial group direct-influence matrix C.

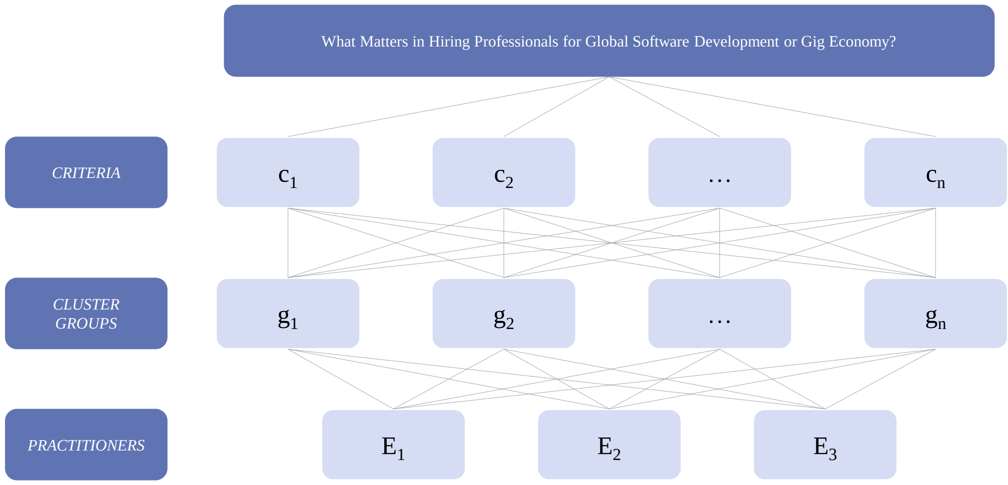


Figure 3.2 – Structure of the problem

Source: Author.

As Fig. 3.2 - Structure of the problem, we evaluate the connection between G cluster groups which correspond to each group of criteria $G = g_1, g_2, \ldots, g_n$ assuming that m experts in a decision group $E = \{e_1, e_2, \ldots, e_m\}$ are asked to indicate the direct influence that a group g_i has on factor g_j, using an integer scale.

The scales 0, 1, 2, 3, and 4 represent the range from "no influence (0)", "low influence (1)", "medium influence (2)", "high influence (3)" to "very high influence (4)", respectively. The notation of g_{ij} indicates the degree to which the respondent believes that a group of criteria g_i affects group g_j.

Then, the individual direct-influence matrix $B_m = \left[b_{ij}^m\right]_{g_n \times g_n}$, see Equation 3.1, provided by the mth expert can be formed, where all principal diagonal elements are equal to zero and b_{ij}^m represents the judgment of decision maker E_m. Where g_n is the total of cluster groups, and m is the number of practitioners to be interviewed.

The practitioners indicated the direct influence of each criteria group from an interview. This interview will be a remote interview, and due to the high number of responses, they will be collected directly in a spreadsheet. Fig 3.3 shows an example of the spreadsheet model used to indicate the direct influence of each criteria group, whereby following the arrow in the spreadsheet, the practitioners will be asked how "g_2" influences "$g_1, g_3, \ldots, g_n$". In the darkest color, the diagonal matrix axis gets the influences of the cluster over itself, so it is not necessary to fulfill. Furthermore, for a better understanding, we must go line by line in the spreadsheet, and as soon as the line is completed, we hide it and go to the next cluster.

Thus, we will interview three practitioners ($m = 3$), following the desired benchmarks: a minimum of two years of practical experience in the GSD/GE context; being one of the decision-makers in hiring professionals; above five projects in software development; allowing the disclosure of results; and large company size. Nevertheless, the data input is significant,

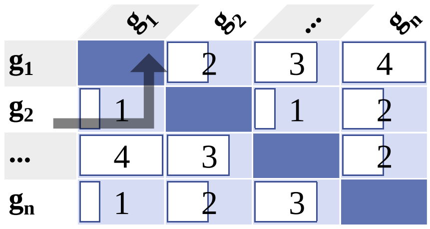


Figure 3.3 – Model of the spreadsheet to indicate the direct influence of each criteria group

Source: author.

as we underline in Subsection 1.4. It demands more than 3 hours, so the DEMATEL method takes the opinion of a few practitioners. Also, we intend to choose female and male specialists, and also a different point of view, as a decision-maker, an outsourcing worker, and a computer science teacher with international development expertise.

By aggregating the m experts' opinions, the group direct-influence matrix $B = \left[b_{ij}^{m}\right]_{g_n \times g_n}$ can be obtained by the Equation 3.1,

$$B = \left[b_{ij}\right]_{g_n x g_n} = \begin{bmatrix} 0 & \frac{1}{3}\sum_{p=1}^{3} b_{12}^{p} & \dots & \frac{1}{3}\sum_{p=1}^{3} b_{1j}^{p} \\ \frac{1}{3}\sum_{p=1}^{3} b_{21}^{p} & 0 & \dots & \frac{1}{3}\sum_{p=1}^{3} b_{2j}^{p} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{3}\sum_{p=1}^{3} b_{i1}^{p} & \frac{1}{3}\sum_{p=1}^{3} b_{i2}^{p} & \dots & 0 \end{bmatrix} \tag{3.1}$$

where m is the number of practitioners to be interviewed which is 3 and g_n is the number of cluster groups.

The initial group direct-influence matrix $B = \left[b_{ij}^{m}\right]_{g_n \times g_n}$ is also named the average matrix. The matrix B illustrates the initial direct effects a group of criteria exerts and receives from other groups.

- ***Step 2:*** Calculate the normalized initial direct-relation matrix.

After we obtained the group direct-influence matrix B, the normalized direct-influence matrix $X = \left[x_{ij}\right]_{g_n \times g_n}$ can be achieved by the Equation 3.2,

$$X = \frac{B}{max\left(\max_{1\le i\le g_n}\sum_{j=1}^{g_n} c_{ij}, \max_{1\le i\le g_n}\sum_{i=1}^{g_n} c_{ij}\right)}, \tag{3.2}$$

where, all elements in the matrix X are complying with $0 \le x_{ij} < 1$.

- ***Step 3:*** Construct the total-influence matrix T.

Using the normalized direct-influence matrix X, the total-influence matrix $T = \left[t_{ij}\right]_{g_n \times g_n}$ is then computed by summing the direct and indirect effects by Equation 3.3 in a matrix operation.

$$T = X(I - X)^{-1}, \tag{3.3}$$

where I is denoted as an identity matrix and X is the normalized direct-influence matrix.

- ***Step 4:*** Compute dispatcher group and receiver group.

For the total-relation matrix T see Equation 3.4, calculate the sum of columns R (Equation 3.5) and rows D (Equation 3.6) for the elements, as follows:

$$T = [t_{ij}]_{g_n \times g_n}, \ (i, j = 1, 2, \ldots, g_n) \tag{3.4}$$

where, g_n corresponds to the total number of criteria groups, and,

$$R = [r_i]_{g_n x1} = \left[\sum_{j=1}^{g_n} t_{ij} \right]_{g_n x1} \quad , \ j \in \{1, 2, \ldots, g_n\} \tag{3.5}$$

and,

$$D = [d_j]_{1xg_n} = \left[\sum_{i=1}^{g_n} t_{ij} \right]_{1xg_n}^{T} \quad , \ i \in \{1, 2, \ldots, g_n\} \tag{3.6}$$

where r_i is the ith row sum in the matrix T and displays the sum of direct and indirect effects dispatching from group C_i to the other factors. Similarly, d_j is the jth column sum in the matrix T and depicts the sum of direct and indirect effects that factors are receiving from the other factors.

- ***Step 5:*** Create an Influential Relation Map (IRM).

For producing a causal diagram, we follow the exact step 5 as the Subsection 2.3.1. The sum of the rows and the columns are indicated separately as vectors D and R within the total relation matrix T. We can obtain a causal and effect plot by mapping the dataset (R + D; R - D). The horizontal axis vector (R + D) called "Prominence" is made by adding D to R, demonstrating the criterion's importance. Similarly, the vertical axis (R - D) called "Relationship" is constructed by subtracting R from D, which can group criteria into a group of causes if positive. Alternatively, if the (R - D) is negative, the criterion is grouped into the effect group, as shown in Table 3.2 - Dataset of Influential Relation Map (IRM). Figure 2.22 shows the Four-quadrant IRM.

Table 3.2 – Dataset of Influential Relation Map (IRM)

Cluster	R	D	**Prominence**	**Relationship**	**Identified as**
G	$\left[\sum_{j=1}^{g_n} t_{ij}\right]_{g_n x1}$	$\left[\sum_{i=1}^{g_n} t_{ij}\right]_{1xg_n}^{T}$	$(R + D)$	$(R$ - $D)$	*Cause*: $(R$ - $D) \geq 0$. *Effect*: $(R$ - $D) < 0$.

Source: Author.

Therefore we built a Table for cluster groups $G = \{g_1, g_2, \ldots, g_n\}$, similar as Table 3.2. In sequence, we present the optional DEMATEL steps that we carry out in this work.

- ***Step 6:*** Optional DEMATEL steps

(a) Set a threshold value to draw the IRM: we used the threshold value φ as the mean of all matrix elements T.

(b) The inner dependency matrix $T^{'}$ is derived based on the threshold value φ, and only factors whose effects on the matrix T are greater than φ are shown in the matrix $T^{'}$.

(c) Based on the value of Table 3.2 - Dataset of Influential Relation Map (IRM), we classify the factors into four quadrants according to their locations in the diagram, where $(R + D)$ is the horizontal axis vector and $(R - D)$ is the vertical axis vector; similar to those shown in Figure 2.22 - DEMATEL four-quadrant Influential Relation Map (IRM). Also, We split the IRM into four quadrants, I to IV, by calculating the mean of $(R + D)$.

After fulfilling the DEMATEL step, we present how we build a semantic textual similarity using the NLP algorithm.

3.2.2 Semantic text similarity (STS)

This section will show how we can use NLP Transformers (Subsection 2.2.5) and Sentence-BERT (Subsection 2.2.8) to create the Word embedding (Subsection 2.2.2) to measure the semantic text similarity (STS). With the STS, we build the third axis of the 3D systematic approach to the hierarchical structure of cluster groups.

A large part of NLP counts on similarity in high-dimensional spaces. Generally, an NLP resolution assumes some text, processes it to build a large vector/array denoting that text, and then executes diverse transformations. Semantic text similarity (STS) is one of the clearest examples of how effective highly-dimensional spaces can be. The logic is: to take a sentence and convert it into a vector; to take many other sentences and convert them into vectors; to find sentences that have the smallest distance (Euclidean) or smallest angle (cosine similarity) between them (PALMA; ATKINSON, 2018; BRIGGS, 2021).

Hugging Face [2] provided a pre-trained BERT model and developed a base class named Pre-Trained-Model. By installing this class, we can load a model from a pre-trained model configuration. In addition, Hugging Face provides modules in TensorFlow and PyTorch. Excellent AI research teams use either or both environments. We use *Sentence-transformers*, a Python framework for state-of-the-art sentence, text, and image embeddings (DEVINE *et al.*, 2021; WOLF *et al.*, 2019). In this work, we use the Pre-Trained-Model "sentence-transformers/all-mpnet-base-v2"[3] due to its high average performance, which is the same Pre-Trained-Model as what we already use to cluster the criteria.

[2] https://huggingface.co/docs/transformers/index
[3] https://huggingface.co/sentence-transformers

Fig. 3.4 shows the base model (BRIGGS, 2021; PRITZKAU, 2021). So within that base model, we have several encoders, and at the bottom, we can see the tokenized text where we have 512 tokens; however, in this thesis, we used 384 tokenized text to have a not-so-large criteria group definition.

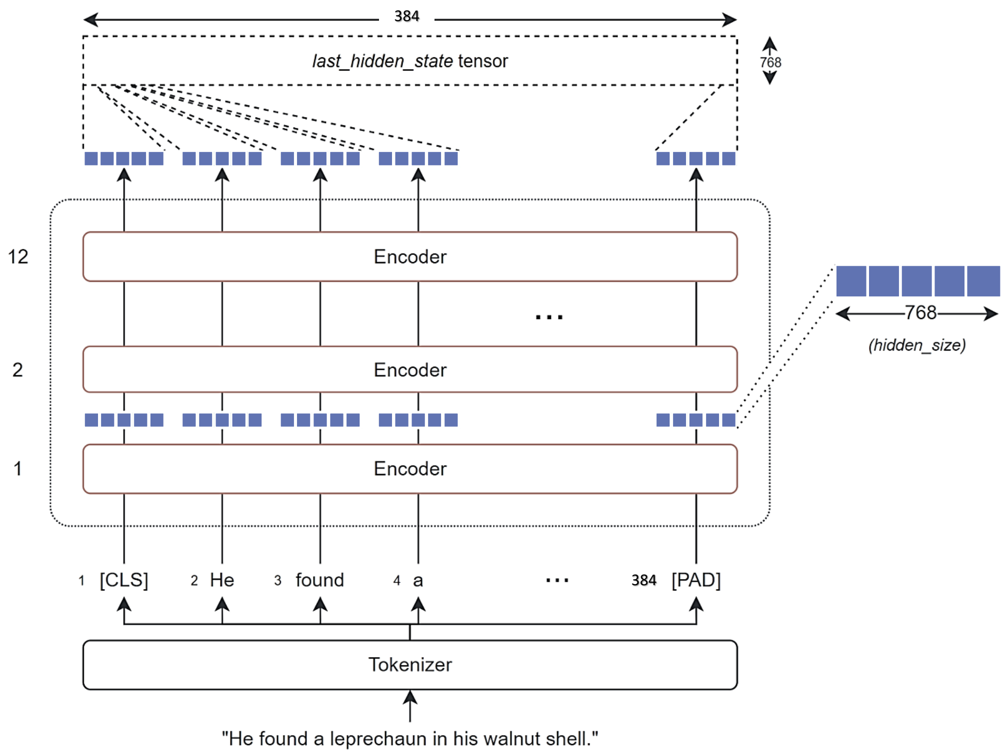


Figure 3.4 – BERT base network using 12-layer transformer network

Source: Adapted from Briggs (2021) and Pritzkau (2021)

Foremost, in a Python framework, we need to create the "*last_hidden_state*" and import the model. Thus, to initialize the model, we import the cluster groups definitions and then tokenize them. At this point we have g_n sentences each containing 768 values. We process these tokens through our model. Inside the *last_hidden_state* tensor outputs contain our text's dense vector representations. Than, the reformatted list of tensors is a single tensor, where this "$tokens[input\_ids]$" is g_n x 384 matrix. We have g_n sentences and 384 tokens.

Then we pass our "$tokens[input\_ids]$" in the "sentence-transformers/all-mpnet-base-v2" model which performs this logic. Then we have an output object comprised of the "*last_hidden_state*" tensor and in the format of $mean\ polling$.

Next, we take our "*last_hidden_state*" tensor and execute the $mean\ polling$ operating to convert it into a sentence vector. This "*dense vectors embeddings*" have the size of g_n x 384 x 768, which g_n is the sentences per 384 tokens per 768 dimension size of the "*last_hidden_state*" tensor.

After producing our "*dense vectors embeddings*", we must execute a "*mean pooling*" operation to assemble a single vector encoding (the sentence embedding). So, we multiply each value in our embedding tensor by its respective "*Attention Mask*" (see Subsection 2.2.5.1) value to ignore non-real tokens. The "*Attention Mask*" tenses comprise only the number one (real-tokens) and zero (padding tokens).

So we must transform the initial *attention* shape to the same model dimension (g_n x 384 x 768). Next, we need to add this other model the dimension of 768, aiming to multiply by the "*dense vectors embeddings*", to take out any activations where there should be only padding tokens. Thus, each vector denotes a single "*attention mask token*", where each token now has a vector of size 768 representing its *Attention mask status*.

Hence, we multiply these two tensors "*dense vectors embeddings*" per "*attention mask token*" to apply the attention mask to our sentence embeddings and get our "*mask embeddings*". Now we need to convert the 384 tokens to only one token. Thus, we sum all within 384 tokens the remained of embeddings along axis 1, obtaining the "*Summed matrix*".

In sequence, we use Torch Clamp [4] to sum the number of values that must be given attention in each position of the tensor, getting the "*Counts matrix*".

Finally, we calculate the mean as the sum of the embedding activations "*Summed matrix*" divided by the number of values that should be given attention in each position "*Counts matrix*". Now, by using these result "*Mean pooled dense vectors*" or sentence vectors, to compare the clusters.

Finally, we must compare the value of "*Mean pooled dense vectors*" using the *cosine similarity* Equation 2.6. In addition, we use the cluster group with the highest number of criteria to be the central cluster compared with other cluster groups. Consequently, the highest value of *cosine similarity* is the most similar.

Now, with all the data, we present how we built the innovative proposed hierarchical structure in the following subsection.

3.2.3 The proposed method

A novel methodology integrates three main concepts and strategies already presented.

Firstly, by a SLR we collected the $c_1, c_2, \ldots, c_{nnn}$ criteria. Then, we use the algorithms NLP/SBERT to get the sentence embeddings, and *k*means to cluster the list of criteria and get criteria clusters $G = g_0, g_1, \ldots, g_n$.

Secondly, we apply the DEMATEL MCDM method for the cluster groups, where we utilize the Influential Relation Map (IRM) to take the $R_i - D_i$ and $R_i + D_i$ (see Table 3.2 - Dataset of Influential Relation Map (IRM)) to create the axes x and y of the 3D hierarchical graph.

Thirdly, we utilize the STS (NLP/SBERT) algorithm, a Pre-Trained Model, to create the *cosine similarity between the criteria cluster definitions*. Thus, we export all the data to a

[4] https://pytorch.org/docs/stable/generated/torch.clamp.html

spreadsheet and join the database.

Finally, to build the hierarchical clustering, we follow the *third phase* steps of the thesis *third stage methodology*:

(a) We create the final cluster groups using the Ward linkage (hierarchical clustering) and produce a dendrogram utilizing the Minitab®. For this, we utilize the data $R_i - D_i$, $R_i + D_i$ (see Table 3.2 - Dataset of Influential Relation Map (IRM)), and STS (*cosine similarity between the cluster groups definitions*) and the standardized variables.

(b) Using the same dataset in the Python framework, we create a 3D bubble chart to display the hierarchical clustering 3D interactive graph for the hierarchical structure of the clusters for hiring professionals.

(c) Finally, we analyze these data that propose a hierarchical structure of grouping criteria for hiring self-employed professionals in the GSD or GE context.

The concepts initially presented in the scientific foundation and in the methodology were summarized in these planned steps, which will be applied in the next chapter to generate the results.

4 RESULTS AND DISCUSSION

This chapter presents the results and discussions the practical applications of the developed methods. So, progressively, the results are described like the steps performed. One of this work's main concerns was presenting the results in an innovative and responsive model. Thus, the results concisely establish the natural conditions to evaluate the performance obtained by applying the proposed method.

We have divided this chapter by following the methodology sections. First, we show the initial clustering process of NLP hierarchical structure 2D, then the results of the DEMATEL methods, the result of the semantic textual similarity, and finally, the aggregated results in the proposed method.

4.1 NLP hierarchical structure 2D of the Criteria clusters

Then, we followed three steps: SBERT, *k*means clustering, and a cluster of the clusters mind map.

Firstly, we select the Sentence-BERT (SBERT) pre-trained BERT network, with the model name "all-mpnet-base-v2" due to its high average performance in semantic search [1]. Then, we compute the sentence embeddings in a Python framework.

Secondly, we apply the *k*means clustering approach in a Python framework, varying from 16 to 25 initial clusters. Thus, due to the high number of criteria (319), the proper number of criteria clusters was 25. Furthermore, we built the word cloud for each cluster to help create cluster names. Appendix C displays the Algorithm 3 - SBERT and *k*means Criteria Cluster. In addition, the algorithm and the word clouds are present in the link [2].

Finally, we displayed the 25 clusters, the cluster group of the clusters formed, and its mind map in the following Subsection 4.1.1.

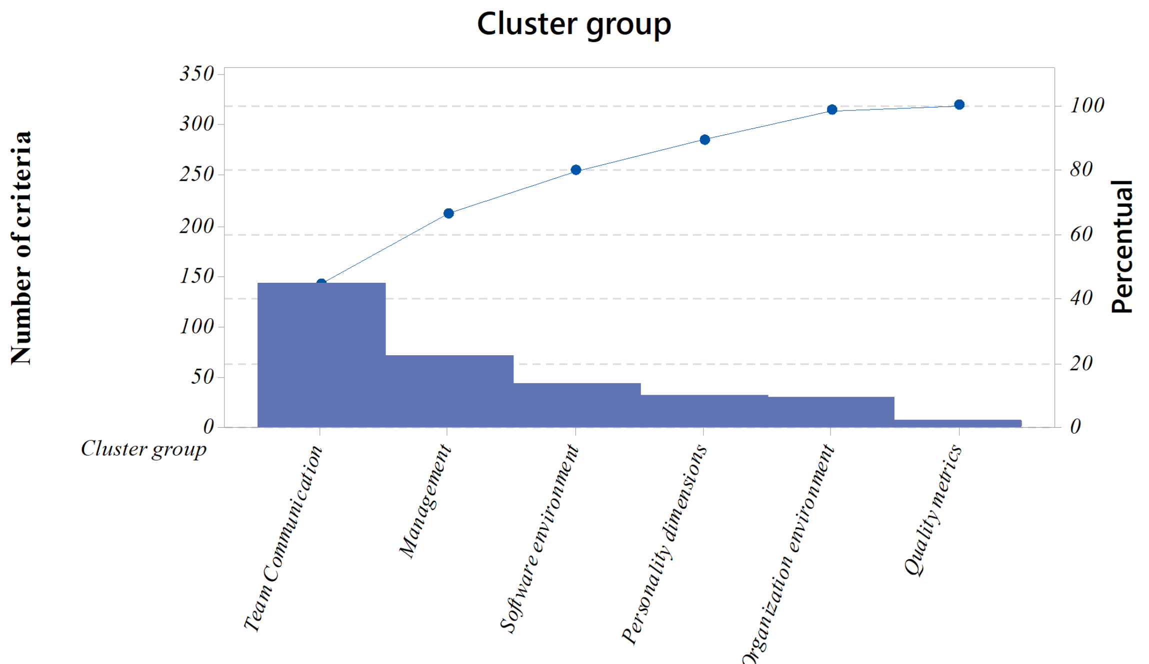
4.1.1 Cluster of the clusters' Mind Map

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 put together the 25 clusters in a spreadsheet and repeated the same clustering algorithm (Algorithm 3 - SBERT and *k*means Criteria Cluster) varying from 4 to 6 clusters, where the better cluster group was 6. Consequently,

[1] https://www.sbert.net/docs/pretrained_models.html
[2] http://bit.ly/3WGtKCP

we created a cluster group word cloud to support creating cluster group names. This algorithm and the cluster group word clouds are present in the link [3].

Fig. 4.1 shows the composition of cluster groups of the clusters formed. This Pareto chart made in Minitab® shows respectively the highest criteria composition were: Team Communication (142 criteria), Management (70 criteria), Software environment (42 criteria), Personality dimensions (31 criteria), Organization environment (29 criteria), and Quality metrics (5 criteria).



Cluster group	Team Communication	Management	Software environment	Personality dimensions	Organization environment	Quality metrics
Number of criteria	142	70	42	31	29	5
Percentual	44,5	21,9	13,2	9,7	9,1	1,6
Acum %	44,5	66,5	79,6	89,3	98,4	100,0

Figure 4.1 – Cluster group composition

Source: author.

It is important to emphasize that the number of times each criterion was mentioned in the SLR database did not influence the grouping algorithm. Also, although the *k*means cluster might produce clusters differently for each run, we used 300 iterations to get a more suitable cluster. Furthermore, the sentence embeddings produced by the SBERT algorithm were so responsive that, for example, we could run the algorithm multiple times; however, it produced the same cluster every time.

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. 4.2 - What Matters in Hiring Professionals for GSD - Cluster of the clusters' mind map. Moreover, in an online view, we suggest first seeing the mind map, then clicking on the respective cluster table. Then, in the cluster table, to see the criterion definition, click on its table number. Thereby, in the criteria table with definitions, in the table footer, click on the number of Fig. 4.2 to repeat

[3] http://bit.ly/3I2drfr

Figure 4.2 – What Matters in Hiring Professionals for GSD - Cluster of the clusters' mind map

Source: author.

this process.

The first cluster group displayed is Team Communication, which comprises Cluster g_2: Team organization and attitude - 1/8 [ng_1: Team Communication] (Table 4.1), Cluster g_3: Stakeholders - 2/8 [ng_1: Team Communication] (Table 4.2), Cluster g_5: Communication - 3/8 [ng_1: Team Communication] (Table 4.3), Cluster g_9: Team skills - 4/8 [ng_1: Team Communication] (Table 4.4), Cluster g_{10}: Task responsibilities - 5/8 [ng_1: Team Communication] (Table 4.5), Cluster g_{14}: Team relationship - 6/8 [ng_1: Team Communication] (Table 4.6), Cluster g_{17}:

Conflict management - 7/8 [ng_1: Team Communication] (Table 4.7), and Cluster g_{21}: Knowledge transfer - 8/8 [ng_1: Team Communication] (Table 4.8). 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. 2.3 - Top 14 highly cited criteria in the SLR. 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 4.1 – Cluster g_2: Team organization and attitude - 1/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C029	Contribution to team effort	3 (5%)	2.7
C037	Contributing to discussions	1 (2%)	2.7
C039	Communicate clearly with team	1 (2%)	2.7
C058	Continuous organisational support	4 (6%)	2.8
C118	Problem solving	3 (5%)	2.9
C141	Participation and support to solve issues	5 (8%)	2.10
C142	Persistent, conscientious responsiveness information of teams	2 (3%)	2.10
C152	Brainstorming actions for organizations	1 (2%)	2.10
C153	Flexibility among teams	2 (3%)	2.10
C202	Capability to adopt team members	1 (2%)	2.11
C217	Team rewards and recognitions	1 (2%)	2.12
C218	Employee facilitation	3 (5%)	2.12
C236	Team member's attitude	1 (2%)	2.12
C273	Charismatic leadership	1 (2%)	2.13
C281	Experienced staff	2 (3%)	2.13
C285	Organizational commitments	1 (2%)	2.14
C316	Team Empowerment	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.2.*

Source: author.

Table 4.2 – Cluster g_3: Stakeholders - 2/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C040	Communicate civility with team	1 (2%)	2.7
C041	Communicate clearly with stakeholders	1 (2%)	2.7
C042	Communicate civility with stakeholders	1 (2%)	2.7
C128	Globally compete to market	2 (3%)	2.10
C151	Understanding over the client's business process environment	6 (9%)	2.10
C177	Stakeholder: Client	2 (3%)	2.11
C178	Stakeholder: Relationship	3 (5%)	2.11
C179	Stakeholder engagement	3 (5%)	2.11
C181	Stakeholder Performance Domain	1 (2%)	2.11
C182	Stakeholder: problem domain	2 (3%)	2.11

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.5.*

Source: author.

The second cluster group shown is Personality dimensions comprising Cluster g_7: Scientific attitude - 1/3 [ng_2: Personality dimensions] (Table 4.9), Cluster g_{13}: Gender segregation (Women) - 2/3 [ng_2: Personality dimensions] (Table 4.10), and Cluster g_{19}: Personality dimensions - 3/3 [ng_2: Personality dimensions] (Table 4.11). 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) (TRINKENREICH *et al.*, 2022; CHURCHILL; CRAIG, 2019), 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 are unexpected research discoveries, such as

Table 4.3 – Cluster g_5: Communication - 3/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C001	Communication	33 (51%)	2.7
C003	Cultural differences among teams	27 (42%)	2.7
C004	Temporal issues	22 (34%)	2.7
C005	Fear impact	2 (3%)	2.7
C006	Employee Satisfaction	5 (8%)	2.7
C020	Relevant information disclosure	4 (6%)	2.7
C024	Technical support	3 (5%)	2.7
C025	Communication Tools	6 (9%)	2.7
C053	Response/ feedback online	4 (6%)	2.8
C060	Task synchronization	6 (9%)	2.8
C062	Geographical dimension	16 (25%)	2.8
C063	Organizational dispersion	7 (11%)	2.8
C076	Relationship between person at different sites	4 (6%)	2.8
C103	Task updating	4 (6%)	2.9
C186	Working and workplace atmosphere	1 (2%)	2.11
C191	Tools and technology: process selection	3 (5%)	2.11
C206	Face to face meeting	6 (9%)	2.11
C210	Technical Infrastructure	6 (9%)	2.12
C235	Socio-culture distance	2 (3%)	2.12
C238	Cost and logistics of meetings	1 (2%)	2.12
C239	Effort to initiate contact	1 (2%)	2.12
C240	Time overlapping	2 (3%)	2.12
C241	Communication frequency	5 (8%)	2.12
C242	Detailed level of communication	2 (3%)	2.12
C244	Domain of manager's opinion	1 (2%)	2.12
C245	Connectivity issues	2 (3%)	2.12
C246	Degree of infrastructure	6 (9%)	2.13
C247	Quality of telecommunication bandwidth	1 (2%)	2.13
C262	Interpersonal relationships skills	3 (5%)	2.13
C275	Frequent information sharing	5 (8%)	2.13
C279	Use of English for communication	1 (2%)	2.13
C280	Informal communication	4 (6%)	2.13
C307	Degree of communication concreteness	2 (3%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.1.*

Source: author.

Table 4.4 – Cluster g_9: Team skills - 4/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C002	English domain	19 (29%)	2.7
C012	Defined of roles and responsibilities	16 (25%)	2.7
C013	Technical requirements	2 (3%)	2.7
C026	Proficiency in a programming language	6 (9%)	2.7
C027	Experience in similar projects	4 (6%)	2.7
C045	Comprehension ability	2 (3%)	2.8
C052	Skilled human resources	5 (8%)	2.8
C109	Expert area (prior experience)	2 (3%)	2.9
C110	Scrum expertise	2 (3%)	2.9
C149	Pilot knowledge between teams	2 (3%)	2.10
C193	Tools and technology: management decision	2 (3%)	2.11
C200	Team size/ structure	9 (14%)	2.11
C255	Specialty ability of the teams	1 (2%)	2.13
C263	Reasoning skills	2 (3%)	2.13
C265	Communication skills in a second language	3 (5%)	2.13
C304	Total number of technical skills (one employee)	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.3.*

Source: author.

Lifelong Learning (C289) and Religion and political attitudes (C124), which 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 4.12 - Cluster g_{12}: Quality metrics - 1/1 [ng_3: Quality metrics], 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. 4.1 - Cluster group composition. The most cited criterion in this cluster in Metrics (C162), with four citations, concerns automated, semi-automated, and manual metrics in risk and quality evaluations.

Table 4.5 – Cluster g_{10}: Task responsibilities - 5/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C012	Defined of roles and responsibilities	16 (25%)	2.7
C017	Coordination challenges level	26 (40%)	2.7
C018	Transparency of roles and responsibilities	6 (9%)	2.7
C030	Accomplishment of assigned responsibilities	2 (3%)	2.7
C031	Task efficiency	2 (3%)	2.7
C032	Tasks effectiveness	1 (2%)	2.7
C046	Assignment of roles and responsibilities	3 (5%)	2.8
C078	Criticality of the task	1 (2%)	2.8
C079	Complexity of the task	1 (2%)	2.8
C080	Degree of Task formality description	1 (2%)	2.8
C139	Workload	4 (6%)	2.10
C140	Task Size	1 (2%)	2.10
C305	Degree of task information	2 (3%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.4.*

Source: author.

Table 4.6 – Cluster g_{14}: Team relationship - 6/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C008	Degree of cooperation	14 (22%)	2.7
C014	Effective Partitioning	2 (3%)	2.7
C021	Team issues	19 (29%)	2.7
C051	Strong team relationship	7 (11%)	2.7
C077	Common working experience	2 (3%)	2.8
C082	Degree of collaborative task coupling	2 (3%)	2.8
C086	Number of involved sites	1 (2%)	2.9
C088	Learning curve	2 (3%)	2.9
C090	Vision for the end product	1 (0%)	2.9
C108	Cross-functional teams	3 (5%)	2.9
C135	Task site dependency	2 (3%)	2.10
C146	Mutual coordination among team members (managerial practices)	3 (5%)	2.10
C174	Inter-team culture (NCASN)	1 (2%)	2.11
C201	Team cohesion	4 (6%)	2.11
C213	Productivity	1 (2%)	2.12
C230	Task allocation	4 (6%)	2.12
C243	Mutual understanding	1 (2%)	2.12
C251	knowledge creation ability among the teams	3 (5%)	2.13
C253	Cooperation and competition within the teams' to fulfill the goals	2 (3%)	2.13

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.2.*

Source: author.

Table 4.7 – Cluster g_{17}: Conflict management - 7/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C010	Effective leadership	14 (22%)	2.7
C011	Project failure risk	5 (8%)	2.7
C064	Turnover (team/staff)	2 (3%)	2.8
C074	Availability of human resources	14 (22%)	2.8
C087	Time pressure	4 (6%)	2.9
C091	Overloading of key personnel	1 (2%)	2.9
C115	Conflict management	5 (8%)	2.9
C116	Flexibility	3 (5%)	2.9
C117	Handling stress	1 (2%)	2.9
C130	Management commitment	4 (6%)	2.10
C136	Personal availability	1 (2%)	2.10
C192	Project management performance	2 (3%)	2.11
C203	Team experience	5 (8%)	2.11
C208	Labor cost	2 (3%)	2.11
C209	Human related problems	1 (2%)	2.12
C220	Project instability	2 (3%)	2.12
C234	Handling soft issues	1 (2%)	2.12
C248	Lack of ICT and technological cohesion	4 (6%)	2.13
C278	Financial maturity	2 (3%)	2.13
C283	Budget constraints	2 (3%)	2.13
C310	Lack of long-term planning	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.1.*

Source: author.

The fourth cluster group shown is Management, comprising Cluster g_1: Agile and training - 1/6 [ng_4: Management] (Table 4.13), Cluster g_8: Project requirements - 2/6 [ng_4:

Table 4.8 – Cluster g_{21}: Knowledge transfer - 8/8 [ng_1: Team Communication]

Code	Criteria	Cited*	Table**
C009	Precise cost estimation	10 (15%)	2.7
C016	Knowledge interchange rate	20 (31%)	2.7
C023	Software support tools	12 (18%)	2.7
C066	New vendor relationship	1 (2%)	2.8
C067	Updated Knowledge transfer documents	1 (0%)	2.8
C068	Knowledge Codifiability	1 (2%)	2.8
C144	Capacity to absorb technical and business knowledge	1 (2%)	2.10
C145	Understanding the process	5 (8%)	2.10
C148	Knowledge incentive toward client business process	3 (5%)	2.10
C154	Learning of innovative technology	4 (6%)	2.10
C196	Knowledge assets	1 (2%)	2.11
C254	Explicit and standard communication pattern for knowledge transfer effectiveness	2 (3%)	2.13
C257	Assessment of teams knowledge transfer effectiveness	2 (3%)	2.13

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.4.*

Source: author.

Table 4.9 – Cluster g_7: Scientific attitude - 1/3 [ng_2: Personality dimensions]

Code	Criteria	Cited*	Table**
C033	Independence of thought and action	2 (3%)	2.7
C035	Scientific attitude	1 (2%)	2.7
C268	Computer anxiety (personality dimensions)	1 (2%)	2.13
C294	Lack of conviction issues	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.7.*

Source: author.

Table 4.10 – Cluster g_{13}: Gender segregation (Women) - 2/3 [ng_2: Personality dimensions]

Code	Criteria	Cited*	Table**
C295	Gender preference and segregation	3 (5%)	2.14
C296	Work-Life Balance Issues (Women)	1 (2%)	2.14
C297	Benevolent Sexism (Women)	1 (2%)	2.14
C298	Lack of Recognition (Women)	1 (2%)	2.14
C299	Lack of Peer Parity (Women)	1 (2%)	2.14
C300	Impostor phenomenon (Women)	1 (2%)	2.14
C301	Pay inequality between genders (Women)	1 (2%)	2.14
C302	Prove-it Again (Women)	1 (2%)	2.14
C303	Maternal Wall (Women)	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.6.*

Source: author.

Table 4.11 – Cluster g_{19}: Personality dimensions - 3/3 [ng_2: Personality dimensions]

Code	Criteria	Cited*	Table**
C034	Creativity in approach to problem solving	1 (2%)	2.7
C036	Determination and effort	1 (2%)	2.7
C038	Accepting criticism gracefully (personality dimensions)	1 (2%)	2.7
C113	Analytical thinking	1 (2%)	2.9
C114	Time management	3 (5%)	2.9
C124	Religion and political attitudes	5 (8%)	2.9
C252	Ability to solve their professional problems	1 (2%)	2.13
C259	Benevolence	1 (2%)	2.13
C261	Accountability	1 (2%)	2.13
C267	Extroversion (personality dimensions)	1 (2%)	2.13
C269	Self-control (personality dimensions)	2 (3%)	2.13
C270	Sensitivity (personality dimensions)	1 (2%)	2.13
C271	Emotional stability (personality dimensions)	1 (2%)	2.13
C272	Conscientiousness (personality dimensions)	1 (2%)	2.13
C274	Age	1 (2%)	2.13
C289	Lifelong learning	1 (2%)	2.14
C306	Degree of personal information	1 (2%)	2.14
C308	Degree of affective intensity	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.2.*

Source: author.

Table 4.12 – Cluster g_{12}: Quality metrics - 1/1 [ng_3: Quality metrics]

Code	Criteria	Cited*	Table**
C121	Code coverage concepts and tools	2 (3%)	2.8
C162	Metrics	4 (6%)	2.9
C216	Quality of test	1 (2%)	2.11
C317	Metrics to assess risk-based testing	1 (2%)	2.14
C318	Metrics to assess risk-based testing activities (time)	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.7.*

Source: author.

Management] (Table 4.14), Cluster g_{11}: Component integration - 3/6] [ng_4: Management (Table 4.15), Cluster g_{16}: Process management - 4/6 [ng_4: Management] (Table 4.16), Cluster g_{18}: Software changes - 5/6 [ng_4: Management] (Table 4.17), and Cluster g_{23}: Change requirement management - 6/6 [ng_4: Management] (Table 4.18). Nevertheless, with 21.9% of all criteria, this cluster group is the second in terms of criteria composition, as shown in Fig. 4.1 - Cluster group composition. Researchers have satisfactorily explored these topics. Also, when looking at the criteria description, all the clusters in that group are linked.

Table 4.13 – Cluster g_1: Agile and training - 1/6 [ng_4: Management]

Code	Criteria	Cited*	Table**
C048	Team training and monitoring	7 (11%)	2.8
C111	Scrum hours	1 (2%)	2.9
C112	Number of sprints	1 (2%)	2.9
C156	Advance and Uniform Development Environment and Training	5 (8%)	2.10
C282	Agile team training	2 (3%)	2.13
C286	Scaling tools and standards	1 (2%)	2.14
C319	Training of DevOps activities	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.7.*

Source: author.

Table 4.14 – Cluster g_8: Project requirements - 2/6 [ng_4: Management]

Code	Criteria	Cited*	Table**
C019	Reporting requirement	10 (15%)	2.7
C085	Stable requirements	7 (11%)	2.9
C104	Quality assurance procedure	7 (11%)	2.9
C125	Updated requirements	6 (9%)	2.9
C134	Site characteristics	1 (2%)	2.10
C143	Project requirements	5 (8%)	2.10
C147	Clear objective	1 (2%)	2.10
C150	Project functionality toward client's business process	2 (3%)	2.10
C161	Process, Data and Product's Components	3 (5%)	2.10
C180	Stakeholder: requirements	2 (3%)	2.11
C187	Project: Characteristics	1 (2%)	2.11
C188	Requirement estimation	1 (2%)	2.11
C195	Tools and technology: testing accuracy	2 (3%)	2.11
C205	Global project management issues	4 (6%)	2.11
C207	User involvement	2 (3%)	2.11
C214	Project methodology (approach, mentoring)	4 (6%)	2.12
C215	Quality of build	1 (2%)	2.12
C221	Software quality control	3 (5%)	2.12
C237	Customer relationship	5 (8%)	2.12
C250	Communication of customer requirements	2 (3%)	2.13
C284	Project scope	2 (3%)	2.13

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.1.*

Source: author.

The fifth cluster group shown is the Organization environment, as shown in Table 4.19 - Cluster g_0: Social and geological - 1/3 [ng_5: Organization environment], Table 4.20 - Cluster g_{15}: Trust - 2/3 [ng_5: Organization environment], and Table 4.21 - Cluster g_{20}: Organization

Table 4.15 – Cluster g_{11}: Component integration - 3/6] [ng_4: Management

Code	Criteria	Cited*	Table**
C061	Software testing methods	9 (14%)	2.8
C069	Proper documentation	6 (9%)	2.8
C070	Compatibility of data	6 (9%)	2.8
C072	Similar programming languages	3 (5%)	2.8
C089	Integration plan	4 (6%)	2.9
C105	Incremental integration	2 (3%)	2.9
C155	Component or Unit Testing prior to integration	2 (3%)	2.10
C163	Specific Integration Timing	1 (2%)	2.10

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.6.*

Source: author.

Table 4.16 – Cluster g_{16}: Process management - 4/6 [ng_4: Management]

Code	Criteria	Cited*	Table**
C022	Process Management	6 (9%)	2.7
C056	Formal standard and procedures	4 (6%)	2.8
C081	Process phase (lifecycle)	1 (2%)	2.8
C131	Software Process improvement - Consultancy	2 (3%)	2.10
C132	Process improvement evaluation	2 (3%)	2.10
C133	Process improvement standards and procedures	2 (3%)	2.10
C137	Process ownership	3 (5%)	2.10
C249	Uniform processes	2 (3%)	2.13

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.7.*

Source: author.

Table 4.17 – Cluster g_{18}: Software changes - 5/6 [ng_4: Management]

Code	Criteria	Cited*	Table**
C057	Change acceptability	10 (15%)	2.8
C065	Degree of novelty	6 (9%)	2.8
C092	Consistent data	1 (0%)	2.9
C106	Regular deliveries	4 (6%)	2.9
C107	Use of modular approach	3 (5%)	2.9
C122	Refactoring concepts	1 (2%)	2.9
C123	Code-smell concepts	1 (2%)	2.9
C126	Change impact analysis in all sites	3 (5%)	2.9
C129	Progress measure in distributed sites	4 (6%)	2.10
C157	Continuous integration	3 (5%)	2.10
C212	Effort and cost estimation for change	1 (2%)	2.12
C315	Polymorphic design	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.4.*

Source: author.

Table 4.18 – Cluster g_{23}: Change requirement management - 6/6 [ng_4: Management]

Code	Criteria	Cited*	Table**
C047	Transparency of Vision and goal	8 (12%)	2.8
C049	Geographically distributed CCB (change control block)	2 (3%)	2.8
C050	Resistance management of changing	1 (2%)	2.8
C055	Process awareness	6 (9%)	2.8
C083	Degree of Business Process maturity	5 (8%)	2.9
C102	Contract management	3 (5%)	2.9
C127	Management support	3 (5%)	2.9
C159	Configuration management	3 (5%)	2.10
C165	Organization: strategies	1 (2%)	2.10
C189	Collaboration, communication and coordination: inter-team, inter-site	10 (15%)	2.11
C190	Collaboration, communication and coordination: cross-boundary	7 (11%)	2.11
C204	Requirement management	5 (8%)	2.11
C211	Infrastructure	3 (5%)	2.12
C277	Client and vendor organizational management commitment	2 (3%)	2.13

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.3.*

Source: author.

- 3/3 [ng_5: Organization environment]. In terms of 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. 2.3 - Top 14 highly cited criteria in the SLR), an important subject investigated in SLR database (GULZAR *et al.*, 2018). 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.

Table 4.19 – Cluster g_0: Social and geological - 1/3 [ng_5: Organization environment]

Code	Criteria	Cited*	Table**
C043	Collaborative work friendly	2 (3%)	2.7
C059	Frequency of social events	2 (3%)	2.8
C175	Social facilities	1 (2%)	2.11
C176	Social interaction	2 (3%)	2.11
C184	Climatic condition	2 (3%)	2.11
C185	Geological condition	1 (2%)	2.11
C258	Communality	1 (2%)	2.13
C260	Internalised norms	1 (2%)	2.13
C264	Communication protocols and customs	1 (2%)	2.13

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.5.*

Source: author.

Table 4.20 – Cluster g_{15}: Trust - 2/3 [ng_5: Organization environment]

Code	Criteria	Cited*	Table**
C007	Trust building	28 (43%)	2.7
C119	Diplomacy	1 (2%)	2.9
C197	Trust: among team members	3 (5%)	2.11
C198	Trust: cross-boundary	1 (2%)	2.11
C199	Trust: confidence in the company and leadership and other stakeholders	2 (3%)	2.11
C256	Mediating role knowledge transfer	1 (2%)	2.13
C266	Ability to motivate others and create trust	3 (5%)	2.13
C293	Eminence Education	2 (3%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.6.*

Source: author.

Table 4.21 – Cluster g_{20}: Organization - 3/3 [ng_5: Organization environment]

Code	Criteria	Cited*	Table**
C044	Culture of leadership	9 (14%)	2.8
C164	Organization: resource	1 (2%)	2.10
C166	Organization: standard	1 (2%)	2.10
C167	Organization: culture	5 (8%)	2.10
C168	Organization: politics	1 (2%)	2.10
C169	Organization: practices	1 (2%)	2.10
C170	Organization: regulations	1 (2%)	2.11
C171	Organization: environment	1 (2%)	2.11
C172	Organization: structure	2 (3%)	2.11
C173	Organization: size	1 (2%)	2.11
C183	Stakeholder Attitude	1 (2%)	2.11
C287	Error management culture	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.5.*

Source: author.

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 Cluster g_4: Green software development - 1/4 [ng_6: Software environment] (Table 4.22), Cluster g_6: Data environment - 2/4 [ng_6: Software environment] (Table 4.23), Cluster g_{22}: Architectural practices - 3/4 [ng_6: Software environment] (Table 4.24), and Cluster g_{24}: Component interface - 4/4 [ng_6: Software environment] (Table 4.25). We must highlight *cluster 4 Green Sofware Development* (RASHID *et al.*, 2021), with criteria such as E-waste minimization (C312) and Green and sustainable management to product life cycle (C313), demonstrating the current social responsibility worldwide.

Table 4.22 – Cluster g_4: Green software development - 1/4 [ng_6: Software environment]

Code	Criteria	Cited*	Table**
C028	Use of software tools	1 (2%)	2.7
C120	Interfacing with different layers of development framework	3 (5%)	2.9
C276	Requirements elicitation techniques	1 (2%)	2.13
C292	Reuse ability	1 (2%)	2.14
C309	Limited support for reusability	1 (2%)	2.14
C312	E-waste minimization	1 (2%)	2.14
C313	Green and sustainable management of product life cycle	1 (2%)	2.14
C314	Minimal reengineering	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.6.*

Source: author.

Table 4.23 – Cluster g_6: Data environment - 2/4 [ng_6: Software environment]

Code	Criteria	Cited*	Table**
C054	Requirement and data traceability	9 (14%)	2.8
C093	Misspelling in data entry	1 (0%)	2.9
C094	Missing information	1 (0%)	2.9
C095	Data Harmonization	2 (3%)	2.9
C096	Data visualization tools	1 (0%)	2.9
C097	Data aggregation	3 (5%)	2.9
C098	Measuring provenance of data	1 (0%)	2.9
C099	Storage of transition logs	1 (2%)	2.9
C100	Analyze Data in Real Time	3 (5%)	2.9
C101	New visualization techniques and their assessments	1 (2%)	2.9
C194	Tools and technology: defect occurrence	1 (2%)	2.11
C288	Handling of data	1 (2%)	2.14
C290	Legislation and regulation with cloud provider	1 (2%)	2.14
C291	Choose the right cloud service provider	1 (2%)	2.14
C311	Efficient utilization of time and computing resources	1 (2%)	2.14

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.3.*

Source: author.

Table 4.24 – Cluster g_{22}: Architectural practices - 3/4 [ng_6: Software environment]

Code	Criteria	Cited*	Table**
C071	Appropriate architecture	6 (9%)	2.8
C219	Alignment between architectural decisions to organization structure	2 (3%)	2.12
C222	Align architecture with organization arrangement	2 (3%)	2.12
C223	knowledge management practices	3 (5%)	2.12
C224	Communicate architectural decisions to all stakeholders	1 (2%)	2.12
C225	Conformance to share practices	2 (3%)	2.12
C226	Standardize architectural practices	1 (2%)	2.12
C228	Architectural design practices	1 (2%)	2.12
C229	Architecting modeling techniques	1 (2%)	2.12
C231	Architecture-based task allocation	2 (3%)	2.12
C232	Compliance to processes	6 (9%)	2.12
C233	Governance implemented	4 (6%)	2.12

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.5.*

Source: author.

Summarising all 25 clusters, we underline the top five with the most criteria. Thus, Cluster g_5: Communication - 3/8 [ng_1: Team Communication] (Table 4.3) has 33 criteria, the most critical cluster and criteria (C001), as pointed out in the SLR, followed by 21 criteria, Cluster g_{17}: Conflict management - 7/8 [ng_1: Team Communication] (Table 4.7), and Project requirements cluster 8 (Table 4.14). Moreover, Cluster g_{14}: Team relationship - 6/8 [ng_1: Team Communication] (Table 4.6) obtained 19 criteria, and the Cluster g_{19}: Personality dimensions

Table 4.25 – Cluster g_{24}: Component interface - 4/4 [ng_6: Software environment]

Code	Criteria	Cited*	Table**
C073	Product selection and customization (off the shelf)	1 (2%)	2.8
C075	Proper component interfaces	1 (2%)	2.8
C084	Product size	3 (5%)	2.9
C138	Component dependency	1 (2%)	2.10
C158	Interface Compatibility	1 (2%)	2.10
C160	Components evaluation	1 (2%)	2.10
C227	Identifying dependencies on architectural design decision	2 (3%)	2.12

**Times cited and percentage. **Table with the defined criteria. See all the criteria clusters in Fig. 4.2, and its definition in Table G.7.*

Source: author.

- 3/3 [ng_2: Personality dimensions] (Table 4.11) obtained 18 criteria. Nonetheless, we can not 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.

By examining Fig. 4.1 - Cluster group composition, the mind map Fig. 4.2 - What Matters in Hiring Professionals for GSD - Cluster of the clusters' mind map, 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.

Lastly, we highlight that "*Scrum*", the most widely applied Agile methodology (HIDAYATI *et al.*, 2020), was absent in Table 2.3 - Top 14 highly cited criteria in the SLR. Hence, this demonstrates the importance of soft skills rather than hard skills for the GSD/GE context. Furthermore, we present and analyze two criteria present in the SLR database: Scrum expertise (C110) and Scrum hours (C111) (see Table 2.10 - Criteria list for contracting professionals in GSD - 4/10). However, these criteria are in different Criteria clusters: Scrum expertise (C110) in Cluster g_9: Team skills - 4/8 [ng_1: Team Communication] and Scrum hours (C111) in Cluster g_1: Agile and training - 1/6 [ng_4: Management]. Thus, these criteria characterize the importance of their definitions, where one is related to the cluster team skills and the other to the agile and training cluster, probably due to the term previous experience, present in criterion C110, being related to a skill already present in the professional expertise.

These results lead to the *third stage* of this work (See Fig. 3.1 - Research framework of the *second* and *third stages* methodology), as we present in the next Section 4.2.

4.2 3D hierarchical structure of the Criteria clusters

This section, the *third stage* methodology, as shown in Fig. 3.1, presents the results of the proposed method as follows:

- Table 4.26 presents the Criteria cluster list overview, which we can find in sequence: cluster number, criteria cluster name, cluster code, the table number with a link (for online view) containing a list of criteria included in the criteria cluster, and the number of criteria included in the cluster in descending order. Further, Appendix G, by Tables G.1, G.2, G.3, G.4, G.5, G.6, and G.7 show the definition of each Criteria cluster. These Tables present in sequence: cluster number, cluster name, cluster code, and Criteria cluster definition. Thus, with the adjusted Criteria cluster definitions, we enabled the DEMATEL interviews with practitioners.

Table 4.26 – Criteria cluster list overview

Cluster	**Criteria cluster name**	**Code**	**Table**	**Criteria in the cluster group**
5	Communication	COMMUN	Table 4.3	33
8	Project requirements	PROJRE	Table 4.14	21
17	Conflict management	CONFLIC	Table 4.7	21
14	Team relationship	TEAMRE	Table 4.6	19
19	Personality dimensions	PERSDI	Table 4.11	18
2	Team organization and attitude	TEORAT	Table 4.1	17
9	Team skills	TEAMSK	Table 4.4	16
6	Data environment	DATAEN	Table 4.23	15
23	Change requirement management	CHREMA	Table 4.18	14
10	Task responsibilities	TASKRE	Table 4.5	13
21	Knowledge transfer	KNOWTR	Table 4.8	13
18	Software changes	SOFTCH	Table 4.17	12
20	Organization	ORGANI	Table 4.21	12
22	Architectural practices	ARCHPR	Table 4.24	12
3	Stakeholders	STAKEH	Table 4.2	10
0	Social and Geological	SOCGEO	Table 4.19	9
13	Gender segregation (Women)	GENDSE	Table 4.10	9
4	Green software development	GREENS	Table 4.22	8
11	Component integration	INTEGR	Table 4.15	8
15	Trust	TRUST	Table 4.20	8
16	Process Management	PROCMA	Table 4.16	8
1	Agile and training	AGITRA	Table 4.13	7
24	Component interface	INTERF	Table 4.25	7
12	Quality metrics	METRIC	Table 4.12	5
7	Scientific attitude	SCIENT	Table 4.9	4

For an overview of all Criteria cluster, see Fig. 4.2.
For the Criteria clusters definitions, see Appendix G.

Source: author.

- Subsection 4.2.1 show the DEMATEL MCDM (Get 1st and 2nd axis) to get the IRM map and the interviews with three practitioners;

- Subsection 4.2.2 creates the 3rd axis of the 3D systematic approach by using the STS.

- Finally, Subsection 4.2.3 shows the 3D hierarchical structure of the criteria clusters.

4.2.1 DEMATEL results

This subsection presents the DEMATEL MCDM results, where, through the interviews with three practitioners, we show how we obtain the 1st and 2nd axis from the IRM map to make the novel hierarchical structure.

We observed each methodology step presented in Subsection 3.2.1 - DEMATEL Method to present the results as follows.

- ***Step 1***: We obtained the grouped direct-influence matrix B through interviews with three professionals as follows.

As stated in Subsection 3.2.1, we followed the desired benchmarks to invite the practitioners. Therefore, the first practitioner has a Master of Science in Computer Science and a total of five years of experience where: with three years in software development to the needs of the Brazilian and international markets, three years and a half as a Computer Science graduation teacher, and almost a year in the ICT department of a national leader in the group health plan sector.

The second practitioner also holds a Master of Science in Computer Science, more than 13 years of programming experience for the national market, ten years as a Computer Science graduation teacher, and currently works as a Full Stack Developer as outsourcing.

The third practitioner has a Ph.D. in Industrial Engineering and two-year experience in Data Science development solutions worldwide, especially in supply chain solutions. Also has experience being one of the decision-makers in hiring professionals. The corporation works with 91 Fortune Global 100 companies. In 2021, they made 19 consecutive appearances on Fortune's "World's Most Admired Companies" list.

Thus, we remote interviewed the three practitioners and collected the direct influence in a spreadsheet, as shown in Fig 4.3 - Spreadsheet used to indicate the direct influence of each criteria group - example. So, following the arrow in the spreadsheet, as the example, they answered how "*Personality dimensions*" influence "*Team relationship*". In this spreadsheet, if the answer is 0, a bar graph remains unfilled, while if the answer is 4, it is entirely filled, representing its most significant influence. Accordingly, this bar graph is respectively filled according to its significance.

Further, following Equation 3.1 (See Subsection 3.2.1), we aggregated the three specialists' opinions in the following group direct-influence matrix Table 4.27. Appendix D, respectively by Tables D.1, D.2, and D.3 shows the direct-influence matrix of the First, Second and Third Practitioner.

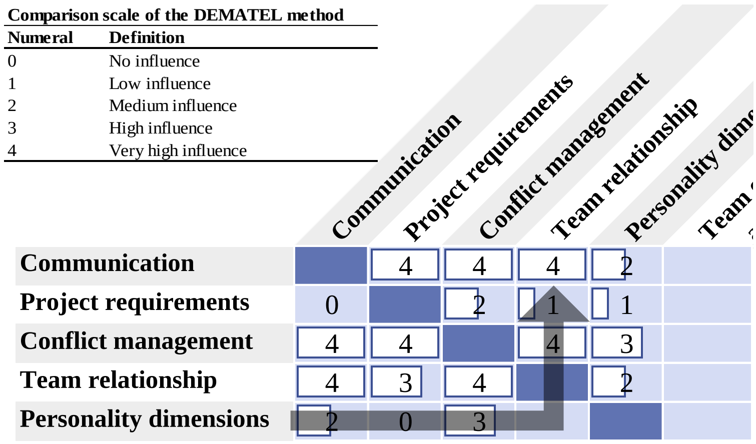


Figure 4.3 – Spreadsheet used to indicate the direct influence of each criteria group - example

Source: author.

- ***Step 2***: the normalized initial direct-relation matrix X, Table 4.28.
- ***Step 3***: total relation matrix $T = X(I - X)^{-1}$, Table 4.29.
- ***Step 4***: the dispatcher group and receiver group, Table 4.30, which provides information on how one factor affects another. We signalized in the column *Identify* if the criteria group is a dispatcher group (cause) or a receiver group (effect).
- ***Step 5***: the Influential Relation Map (IRM), Fig. 4.4.
- ***Step 6a***: the threshold value φ was set as the mean of the values in matrix T', which was 0.0770.
- ***Step 6b***: the inner dependence matrix T', Annex E in Table E.2. All the values different from zero are the only factors whose effects on the matrix T. And Table E.1 shows the connections in the inner dependence matrix. As we did in *Step 4*, we signalized in the column *Identify* if the criteria group is a dispatcher group (cause) or a receiver group (effect), where the results were the same as in *Step 4*.
- ***Step 6c***: we split the IRM into four quadrants, as shown in Fig. 4.4.

Table 4.27 – Grouped direct-influence matrix (B) made with three practitioners

Clusters	COMMUN	PROJRE	CONFMA	TEAMRE	PERSDI	TEORAT	TEAMSK	DATAEN	CHREMA	TASKRE	KNOWTR	SOFTCH	ORGANI	ARCHPR	STAKEH	SOCGEO	GENDSE	GREENSO	INTEGR	TRUST	PROCMA	AGITRA	INTERF	METRIC	SCIENT	S (j)
COMMUN	-	4.00	3.67	4.00	2.33	3.67	2.67	2.67	3.33	3.00	3.33	3.00	3.67	2.33	3.33	2.33	3.00	3.00	2.33	4.00	3.67	3.33	2.67	2.00	2.00	73.33
PROJRE	0.33	-	2.33	1.33	2.00	2.67	3.00	3.33	4.00	3.33	1.33	3.67	1.33	3.67	3.00	0.33	0.67	1.67	2.67	0.67	2.33	2.67	3.00	2.00	3.00	54.33
CONFMA	3.67	2.00	-	4.00	3.00	3.00	1.33	2.67	3.00	2.67	2.67	2.33	1.33	2.00	3.33	1.67	2.00	1.00	1.00	3.67	3.67	2.33	0.67	1.33	2.00	56.33
TEAMRE	3.00	2.67	3.33	-	2.67	3.33	2.67	1.00	2.67	3.33	2.67	2.00	1.67	1.00	1.67	1.00	2.00	1.33	0.67	3.67	3.00	2.67	1.00	1.33	1.67	52.00
PERSDI	2.33	1.33	3.00	3.33	-	3.00	2.00	0.67	1.00	2.33	1.67	1.00	1.67	0.67	2.67	1.67	3.00	1.33	1.00	3.33	1.67	1.67	0.67	0.67	2.67	44.33
TEORAT	3.00	2.33	3.00	3.00	2.33	-	2.33	1.67	2.67	3.33	3.00	1.67	2.00	1.67	2.33	1.67	1.67	1.33	1.67	3.67	3.33	2.33	0.33	1.67	2.00	54.00
TEAMSK	2.00	2.33	1.67	2.00	0.67	2.33	-	3.00	2.33	3.33	2.33	2.00	1.67	3.33	2.00	0.67	0.33	2.67	3.00	3.33	2.33	2.67	3.33	2.33	2.00	53.67
DATAEN	1.67	2.33	1.33	1.00	1.00	1.00	0.67	-	3.00	1.33	0.67	2.00	1.33	2.33	2.00	0.67	0.33	1.33	2.67	3.00	1.33	0.67	1.67	2.00	1.67	37.00
CHREMA	3.00	4.00	3.33	2.00	1.00	1.67	1.33	2.00	-	2.33	1.33	3.33	1.33	1.67	3.67	0.67	-	1.67	2.33	2.00	3.00	1.33	2.33	2.00	2.00	49.33
TASKRE	2.33	2.00	2.67	3.00	3.00	3.00	2.67	2.33	2.67	-	1.00	1.67	1.00	2.00	1.00	1.00	1.67	1.33	2.00	3.33	3.33	2.67	2.00	1.67	2.33	51.67
KNOWTR	3.33	0.67	1.33	3.00	2.33	2.00	2.67	1.00	1.00	2.00	-	0.33	1.33	1.67	0.67	0.33	0.33	3.33	1.00	3.00	2.00	1.67	1.00	1.33	1.67	39.00
SOFTCH	3.00	2.67	3.33	2.00	1.33	1.67	0.67	2.33	3.67	2.67	1.67	-	0.67	3.00	2.33	0.67	0.33	1.67	3.33	1.67	2.33	1.67	2.67	1.67	1.33	48.33
ORGANI	4.00	1.33	3.67	3.00	1.33	3.00	2.00	1.67	2.33	2.00	2.67	1.00	-	1.67	2.67	3.33	3.00	2.33	2.00	4.00	3.33	3.67	1.00	2.67	2.67	60.33
ARCHPR	2.33	1.33	1.33	0.67	0.33	1.33	1.67	2.67	1.67	1.00	1.33	2.33	0.67	-	0.33	0.67	0.33	2.67	3.00	1.33	1.67	1.00	2.33	2.33	1.33	35.67
STAKEH	2.33	2.67	2.67	1.33	2.00	2.33	1.33	1.67	2.67	1.67	0.67	2.67	2.67	1.00	-	1.33	1.67	1.00	1.33	3.67	2.67	1.67	2.33	2.33	1.67	47.33
SOCGEO	3.33	1.00	3.00	2.67	2.33	2.33	1.67	0.67	1.33	1.33	1.67	0.33	1.67	0.33	1.33	-	2.33	0.67	0.33	3.00	2.00	1.67	0.33	0.67	1.33	37.33
GENDSE	3.00	-	2.00	1.67	1.67	1.67	1.67	0.67	0.67	0.67	0.67	0.33	2.33	-	2.00	2.33	-	0.67	0.33	2.00	1.00	0.33	0.33	1.00	0.33	27.33
GREENSO	1.33	1.33	2.00	1.33	1.00	2.67	1.67	2.00	1.33	1.33	2.33	2.00	1.33	2.67	1.33	1.00	-	-	2.67	1.33	1.33	1.33	1.67	1.67	2.00	38.67
INTEGR	1.33	2.33	1.00	0.67	0.33	1.33	1.33	3.00	2.00	1.33	0.67	2.00	0.67	3.00	1.00	0.33	-	2.67	-	1.33	1.67	1.00	1.67	2.00	1.67	34.33
TRUST	4.00	1.67	4.00	3.67	3.33	3.67	2.67	1.00	2.33	2.33	2.00	1.67	3.00	1.33	3.33	1.67	1.33	0.67	1.33	-	2.33	1.67	1.33	2.33	2.33	55.00
PROCMA	3.00	2.67	3.33	3.33	1.67	3.33	2.67	2.33	3.33	3.33	2.00	2.33	2.67	2.00	2.33	1.67	1.00	1.67	2.33	3.00	-	2.33	1.67	3.67	2.00	59.67
AGITRA	3.00	2.33	2.67	2.67	1.67	3.00	2.67	1.33	3.00	3.00	2.00	2.00	2.00	1.33	1.67	1.33	1.00	1.67	1.67	2.67	2.33	-	2.00	1.67	2.00	50.67
INTERF	1.67	2.33	0.67	1.00	0.67	1.00	1.00	1.33	1.67	2.00	0.67	1.00	1.00	2.00	2.00	0.33	0.67	2.33	2.67	1.33	1.00	1.00	-	2.00	1.33	32.67
METRIC	2.33	2.33	2.67	1.67	1.00	2.00	1.33	2.33	1.67	1.67	1.33	2.67	1.00	1.67	2.67	0.67	0.67	2.33	1.67	3.00	2.67	2.00	2.33	-	2.33	46.00
SCIENT	3.33	1.00	2.33	1.33	2.67	3.33	3.67	2.67	1.33	1.67	2.67	1.33	2.67	0.33	2.00	1.00	0.33	1.67	0.67	2.67	1.33	1.33	0.33	2.67	-	44.33
S (i)	62.67	48.67	60.33	53.67	41.67	58.33	47.33	46.00	54.67	53.00	42.33	44.67	40.67	42.67	50.67	28.33	27.67	42.00	43.67	64.67	55.33	44.67	38.67	45.00	45.33	-

For the complete information see Subsection 4.2.1 - DEMATEL results

Source: author.

Table 4.28 – Normalized group direct-influence matrix X

Clusters	COMMUN	PROJRE	CONFMA	TEAMRE	PERSDI	TEORAT	TEAMSK	DATAEN	CHREMA	TASKRE	KNOWTR	SOFTCH	ORGANI	ARCHPR	STAKEH	SOCGEO	GENDSE	GREENSO	INTEGR	TRUST	PROCMA	AGITRA	INTERF	METRIC	SCIENT	S (j)
COMMUN	-	0.05	0.05	0.05	0.03	0.05	0.04	0.04	0.05	0.04	0.05	0.04	0.05	0.03	0.05	0.03	0.04	0.04	0.03	0.05	0.05	0.05	0.04	0.03	0.03	1.00
PROJRE	-	-	0.03	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.02	0.05	0.02	0.05	0.04	-	0.01	0.02	0.04	0.01	0.03	0.04	0.04	0.03	0.04	0.74
CONFMA	0.05	0.03	-	0.05	0.04	0.04	0.02	0.04	0.04	0.04	0.04	0.03	0.02	0.03	0.05	0.02	0.03	0.01	0.01	0.05	0.05	0.03	0.01	0.02	0.03	0.77
TEAMRE	0.04	0.04	0.05	-	0.04	0.05	0.04	0.01	0.04	0.05	0.04	0.03	0.02	0.01	0.02	0.01	0.03	0.02	0.01	0.05	0.04	0.04	0.01	0.02	0.02	0.71
PERSDI	0.03	0.02	0.04	0.05	-	0.04	0.03	0.01	0.01	0.03	0.02	0.01	0.02	0.01	0.04	0.02	0.04	0.02	0.01	0.05	0.02	0.02	0.01	0.01	0.04	0.60
TEORAT	0.04	0.03	0.04	0.04	0.03	-	0.03	0.02	0.04	0.05	0.04	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.05	0.05	0.03	-	0.02	0.03	0.74
TEAMSK	0.03	0.03	0.02	0.03	0.01	0.03	-	0.04	0.03	0.05	0.03	0.03	0.02	0.05	0.03	0.01	-	0.04	0.04	0.05	0.03	0.04	0.05	0.03	0.03	0.73
DATAEN	0.02	0.03	0.02	0.01	0.01	0.01	0.01	-	0.04	0.02	0.01	0.03	0.02	0.03	0.03	0.01	-	0.02	0.04	0.04	0.02	0.01	0.02	0.03	0.02	0.50
CHREMA	0.04	0.05	0.05	0.03	0.01	0.02	0.02	0.03	-	0.03	0.02	0.05	0.02	0.02	0.05	0.01	-	0.02	0.03	0.03	0.04	0.02	0.03	0.03	0.03	0.67
TASKRE	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.04	-	0.01	0.02	0.01	0.03	0.01	0.01	0.02	0.02	0.03	0.05	0.05	0.04	0.03	0.02	0.03	0.70
KNOWTR	0.05	0.01	0.02	0.04	0.03	0.03	0.04	0.01	0.01	0.03	-	-	0.02	0.02	0.01	-	-	0.05	0.01	0.04	0.03	0.02	0.01	0.02	0.02	0.53
SOFTCH	0.04	0.04	0.05	0.03	0.02	0.02	0.01	0.03	0.05	0.04	0.02	-	0.01	0.04	0.03	0.01	-	0.02	0.05	0.02	0.03	0.02	0.04	0.02	0.02	0.66
ORGANI	0.05	0.02	0.05	0.04	0.02	0.04	0.03	0.02	0.03	0.03	0.04	0.01	-	0.02	0.04	0.05	0.04	0.03	0.03	0.05	0.05	0.05	0.01	0.04	0.04	0.82
ARCHPR	0.03	0.02	0.02	0.01	-	0.02	0.02	0.04	0.02	0.01	0.02	0.03	0.01	-	-	0.01	-	0.04	0.04	0.02	0.02	0.01	0.03	0.03	0.02	0.49
STAKEH	0.03	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.04	0.02	0.01	0.04	0.04	0.01	-	0.02	0.02	0.01	0.02	0.05	0.04	0.02	0.03	0.03	0.02	0.65
SOCGEO	0.05	0.01	0.04	0.04	0.03	0.03	0.02	0.01	0.02	0.02	0.02	-	0.02	-	0.02	-	0.03	0.01	-	0.04	0.03	0.02	-	0.01	0.02	0.51
GENDSE	0.04	-	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	-	0.03	-	0.03	0.03	-	0.01	-	0.03	0.01	-	-	0.01	-	0.37
GREENSO	0.02	0.02	0.03	0.02	0.01	0.04	0.02	0.03	0.02	0.02	0.03	0.03	0.02	0.04	0.02	0.01	-	-	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.53
INTEGR	0.02	0.03	0.01	0.01	-	0.02	0.02	0.04	0.03	0.02	0.01	0.03	0.01	0.04	0.01	-	-	0.04	-	0.02	0.02	0.01	0.02	0.03	0.02	0.47
TRUST	0.05	0.02	0.05	0.05	0.05	0.05	0.04	0.01	0.03	0.03	0.03	0.02	0.04	0.02	0.05	0.02	0.02	0.01	0.02	-	0.03	0.02	0.02	0.03	0.03	0.75
PROCMA	0.04	0.04	0.05	0.05	0.02	0.05	0.04	0.03	0.05	0.05	0.03	0.03	0.04	0.03	0.03	0.02	0.01	0.02	0.03	0.04	-	0.03	0.02	0.05	0.03	0.81
AGITRA	0.04	0.03	0.04	0.04	0.02	0.04	0.04	0.02	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.04	0.03	-	0.03	0.02	0.03	0.69
INTERF	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.01	0.01	0.01	0.03	0.03	-	0.01	0.03	0.04	0.02	0.01	0.01	-	0.03	0.02	0.45
METRIC	0.03	0.03	0.04	0.02	0.01	0.03	0.02	0.03	0.02	0.02	0.02	0.04	0.01	0.02	0.04	0.01	0.01	0.03	0.02	0.04	0.04	0.03	0.03	-	0.03	0.63
SCIENT	0.05	0.01	0.03	0.02	0.04	0.05	0.05	0.04	0.02	0.02	0.04	0.02	0.04	-	0.03	0.01	-	0.02	0.01	0.04	0.02	0.02	-	0.04	-	0.60
S (i)	0.85	0.66	0.82	0.73	0.57	0.80	0.65	0.63	0.75	0.72	0.58	0.61	0.55	0.58	0.69	0.39	0.38	0.57	0.60	0.88	0.75	0.61	0.53	0.61	0.62	-

For the complete information see Subsection 4.2.1 - DEMATEL results

Source: author.

Table 4.29 – Total relation matrix $T = X(I - X)^{-1}$

Cluster	COMMUN	PROJRE	CONFMA	TEAMRE	PERSDI	TEORAT	TEAMSK	DATAEN	CHREMA	TASKRE	KNOWTR	SOFTCH	ORGANI	ARCHPR	STAKEH	SOCGEO	GENDSE	GREENSO	INTEGR	TRUST	PROCMA	AGITRA	INTERF	METRIC	SCIENT
COMMUN	0.10	0.13	0.15	0.14	0.10	0.14	0.11	0.11	0.14	0.13	0.11	0.11	0.12	0.10	0.13	0.08	0.09	0.11	0.10	0.16	0.14	0.12	0.10	0.10	0.10
PROJRE	0.08	0.06	0.10	0.08	0.08	0.10	0.09	0.10	0.12	0.11	0.07	0.10	0.07	0.10	0.10	0.04	0.04	0.07	0.09	0.08	0.10	0.09	0.09	0.08	0.09
CONFMA	0.13	0.09	0.08	0.12	0.10	0.12	0.08	0.09	0.11	0.11	0.09	0.09	0.07	0.08	0.11	0.06	0.06	0.07	0.07	0.13	0.12	0.09	0.06	0.08	0.09
TEAMRE	0.12	0.10	0.12	0.07	0.09	0.12	0.09	0.07	0.10	0.11	0.09	0.08	0.07	0.07	0.09	0.05	0.06	0.07	0.06	0.13	0.11	0.09	0.06	0.07	0.08
PERSDI	0.10	0.07	0.10	0.10	0.05	0.10	0.08	0.06	0.07	0.09	0.07	0.06	0.07	0.05	0.09	0.05	0.07	0.06	0.06	0.11	0.08	0.07	0.05	0.05	0.08
TEORAT	0.12	0.09	0.12	0.11	0.09	0.07	0.09	0.08	0.10	0.11	0.09	0.08	0.08	0.08	0.10	0.06	0.06	0.07	0.08	0.13	0.11	0.09	0.05	0.08	0.08
TEAMSK	0.10	0.09	0.09	0.09	0.06	0.10	0.06	0.10	0.10	0.11	0.08	0.08	0.07	0.10	0.09	0.04	0.04	0.09	0.09	0.12	0.10	0.09	0.09	0.09	0.08
DATAEN	0.07	0.07	0.07	0.06	0.05	0.06	0.05	0.04	0.09	0.06	0.04	0.07	0.05	0.07	0.07	0.03	0.03	0.05	0.07	0.09	0.06	0.05	0.06	0.07	0.06
CHREMA	0.11	0.11	0.11	0.09	0.06	0.09	0.07	0.08	0.07	0.09	0.07	0.10	0.06	0.07	0.11	0.04	0.03	0.07	0.08	0.10	0.10	0.07	0.08	0.08	0.08
TASKRE	0.10	0.09	0.11	0.10	0.09	0.11	0.09	0.09	0.10	0.06	0.06	0.08	0.06	0.08	0.07	0.05	0.06	0.07	0.08	0.12	0.11	0.09	0.07	0.08	0.08
KNOWTR	0.10	0.05	0.07	0.09	0.07	0.08	0.08	0.06	0.06	0.08	0.04	0.05	0.06	0.06	0.06	0.03	0.03	0.08	0.05	0.10	0.08	0.06	0.05	0.06	0.06
SOFTCH	0.11	0.09	0.11	0.08	0.06	0.09	0.06	0.08	0.11	0.09	0.07	0.05	0.05	0.09	0.09	0.04	0.03	0.07	0.09	0.09	0.09	0.07	0.08	0.07	0.07
ORGANI	0.14	0.09	0.13	0.12	0.08	0.12	0.09	0.08	0.11	0.10	0.10	0.08	0.06	0.08	0.11	0.08	0.08	0.09	0.08	0.14	0.12	0.11	0.07	0.10	0.10
ARCHPR	0.08	0.06	0.06	0.05	0.04	0.06	0.06	0.07	0.07	0.06	0.05	0.07	0.04	0.04	0.05	0.03	0.02	0.07	0.08	0.07	0.07	0.05	0.06	0.07	0.05
STAKEH	0.10	0.09	0.10	0.08	0.07	0.10	0.07	0.07	0.10	0.08	0.06	0.09	0.08	0.06	0.06	0.05	0.05	0.06	0.07	0.12	0.10	0.07	0.07	0.08	0.07
SOCGEO	0.10	0.06	0.09	0.09	0.07	0.08	0.07	0.05	0.07	0.07	0.06	0.04	0.06	0.04	0.06	0.03	0.06	0.04	0.04	0.10	0.08	0.06	0.04	0.05	0.06
GENDSE	0.08	0.03	0.07	0.06	0.05	0.06	0.05	0.04	0.05	0.04	0.04	0.03	0.06	0.03	0.06	0.05	0.02	0.04	0.03	0.07	0.05	0.04	0.03	0.04	0.03
GREENSO	0.07	0.06	0.08	0.06	0.05	0.08	0.06	0.07	0.07	0.06	0.07	0.07	0.05	0.07	0.06	0.04	0.02	0.04	0.07	0.07	0.07	0.06	0.06	0.06	0.07
INTEGR	0.06	0.07	0.06	0.05	0.04	0.06	0.05	0.08	0.07	0.06	0.04	0.06	0.04	0.07	0.05	0.03	0.02	0.07	0.04	0.07	0.06	0.05	0.05	0.06	0.06
TRUST	0.13	0.09	0.13	0.12	0.10	0.12	0.10	0.07	0.10	0.10	0.08	0.08	0.09	0.07	0.11	0.06	0.06	0.06	0.07	0.09	0.10	0.08	0.07	0.09	0.09
PROCMA	0.12	0.10	0.13	0.12	0.08	0.12	0.10	0.09	0.12	0.12	0.09	0.09	0.09	0.09	0.10	0.06	0.05	0.08	0.09	0.13	0.08	0.09	0.08	0.11	0.09
AGITRA	0.11	0.09	0.11	0.10	0.07	0.11	0.09	0.07	0.11	0.10	0.08	0.08	0.07	0.07	0.08	0.05	0.05	0.07	0.07	0.11	0.10	0.05	0.07	0.08	0.08
INTERF	0.07	0.07	0.05	0.05	0.04	0.06	0.05	0.05	0.06	0.07	0.04	0.05	0.04	0.06	0.06	0.02	0.03	0.06	0.07	0.06	0.05	0.05	0.03	0.06	0.05
METRIC	0.10	0.08	0.10	0.08	0.06	0.09	0.07	0.08	0.08	0.08	0.06	0.08	0.06	0.07	0.09	0.04	0.04	0.07	0.07	0.11	0.09	0.07	0.07	0.05	0.08
SCIENT	0.11	0.07	0.09	0.08	0.08	0.11	0.10	0.08	0.08	0.08	0.08	0.07	0.08	0.05	0.08	0.04	0.04	0.07	0.05	0.10	0.08	0.07	0.05	0.08	0.05
S (i)	2.50	2.01	2.44	2.19	1.71	2.36	1.92	1.87	2.24	2.17	1.74	1.85	1.66	1.74	2.07	1.15	1.13	1.68	1.76	2.60	2.26	1.83	1.58	1.83	1.84

For more details see Subsection 4.2.1

Source: author.

Table 4.30 – Connections in the total relation matrix T

Groups	R_i	D_i	$R_i + D_i$	$R_i - D_i$	Identify
COMMUN	2.93	2.50	5.42	0.43	Cause
PROJRE	2.13	2.01	4.14	0.13	Cause
CONFMA	2.30	2.44	4.74	-0.14	Effect
TEAMRE	2.15	2.19	4.34	-0.04	Effect
PERSDI	1.82	1.71	3.53	0.11	Cause
TEORAT	2.22	2.36	4.58	-0.15	Effect
TEAMSK	2.13	1.92	4.05	0.22	Cause
DATAEN	1.49	1.87	3.36	-0.38	Effect
CHREMA	2.02	2.24	4.26	-0.22	Effect
TASKRE	2.10	2.17	4.27	-0.07	Effect
KNOWTR	1.62	1.74	3.36	-0.12	Effect
SOFTCH	1.94	1.85	3.79	0.09	Cause
ORGANI	2.45	1.66	4.11	0.79	Cause
ARCHPR	1.42	1.74	3.16	-0.32	Effect
STAKEH	1.94	2.07	4.01	-0.13	Effect
SOCGEO	1.57	1.15	2.72	0.42	Cause
GENDSE	1.16	1.13	2.30	0.03	Cause
GREENSO	1.54	1.68	3.22	-0.13	Effect
INTEGR	1.37	1.76	3.13	-0.40	Effect
TRUST	2.28	2.60	4.87	-0.32	Effect
PROCMA	2.43	2.26	4.69	0.16	Cause
AGITRA	2.08	1.83	3.91	0.25	Cause
INTERF	1.31	1.58	2.88	-0.27	Effect
METRIC	1.87	1.83	3.69	0.04	Cause
SCIENT	1.85	1.84	3.69	0.01	Cause

The dispatcher and receiver group.

Source: author.

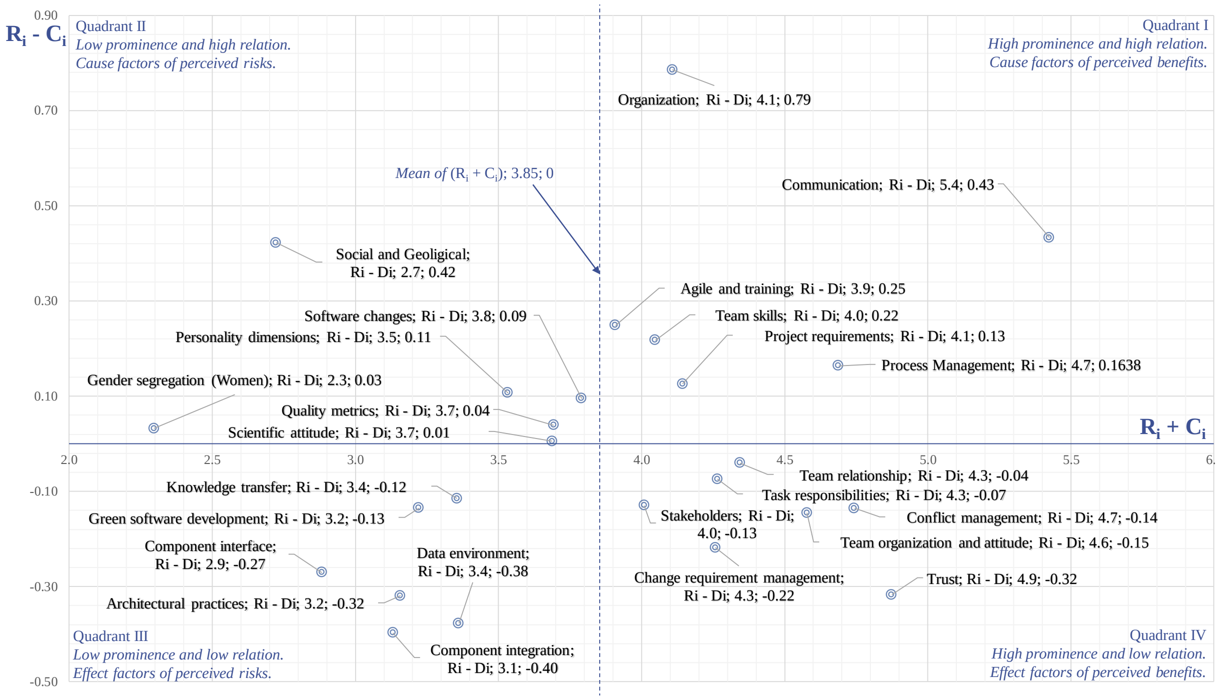


Figure 4.4 – Influential Relation Map (IRM) - four quadrants

Source: author.

The following Subsection 4.2.2 presents the results of the semantic textual similarity of the Criteria clusters.

4.2.2 Semantic Textual Similarities results

The most accessible implementation approach that we have specifically found is through the *sentence-transformers* library — which covers most of this procedure into a few lines of code. "Transformers" is a constant effort supported by the team of engineers and researchers at Hugging Face [4] with assets from a community of over 400 external contributors. The library is released beneath the Apache 2.0 license and is available on GitHub (WOLF *et al.*, 2019).

As shown in Fig. 3.4, we first need to create the *last_hidden_state* and import the model. In a Python framework, we applied the Algorithm 4 - STS cosine similarities between the clusters, as shown in Appendix F.

Then, to initialize the model, we import the sentences dataset (Criteria cluster definitions), see Appendix G - Tables G.1, G.2, G.3, G.4, G.5, G.6, and G.7 with the definitions of each Criteria cluster.

We put the criteria cluster with the most criteria (Cluster g_5: Communication - 3/8 [ng_1: Team Communication], Table 4.3) as the central cluster to be compared with other Criteria clusters. Thus, we tokenize the Criteria cluster definitions (sentences) by our model. Table 4.31 shows the reformatted list of a single tensor for the first Criteria cluster (sentence).

Table 4.31 – Tokens Inputs ids

[tensor	([0, 4811, 3795, 2009, 11710, 2002, 5376, 3975, 2001, 4811, 2003, 2240, 1016, 2003, 2808, 1014, 2000, 4363, 4811, 6079, 2011, 2000, 2626, 2140, 2376, 2154, 1041, 3295, 2353, 2004, 2000, 2346, 2009, 2066, 11904, 2034, 2231, 1015, 2004, 1015, 2231, 3971, 1016, 2173, 3230, 2042, 2053, 4785, 1014, 6786, 1014, 2002, 7195, 6485, 1014, 2033, 2068, 27899, 4811, 3145, 3318, 2047, 3269, 7499, 2017, 2371, 3455, 4285, 10643, 2019, 2011, 2182, 2032, 1016, 15854, 3318, 2028, 3145, 2004, 2000, 2055, 4493, 2094, 2784, 2012, 2151, 8398, 12251, 2002, 10964, 2028, 18640, 2002, 21577, 2000, 6065, 2001, 26355, 8097, 17179, 2275, 8294, 1014, 6796, 1014, 2002, 18781, 7671, 1016, 3283, 2001, 11941, 26247, 3720, 2353, 2004, 6114, 2001, 2010, 19212, 2011, 12199, 3099, 1016, 4363, 6699, 2009, 26355, 8097, 17179, 2275, 4811, 2024, 2040, 1041, 3282, 3895, 5391, 2003, 28181, 2098, 1016, 2042, 2000, 2140, 2781, 2034, 5724, 7718, 1033, 2027, 2728, 7506, 2000, 3280, 2094, 2115, 2016, 2371, 4577, 1014, 4856, 2000, 8118, 21104, 8166, 6133, 6554, 2003, 13300, 2972, 1016, 2353, 2004, 2000, 15854, 3296, 1014, 2000, 2228, 2001, 26355, 8097, 17179, 2275, 4811, 4154, 2629, 1016, 2003, 2240, 1014, 3136, 2231, 1015, 2004, 1015, 2231, 6299, 2068, 9889, 2000, 4499, 2009, 11904, 8294, 1014, 2881, 2004, 1041, 3772, 2001, 2140, 7077, 2002, 2526, 21583, 2795, 1016, 2178, 1014, 2013, 2068, 2026, 2204, 17051, 2002, 2055, 1015, 2639, 2004, 3608, 4707, 2004, 1041, 6560, 3299, 1016, 4091, 4301, 25381, 10454, 14684, 2430, 5504, 4577, 3430, 2023, 18359, 2003, 4811, 2353, 2004, 10664, 3318, 1016, 3741, 2001, 4811, 5910, 2002, 2901, 3181, 2094, 4577, 1016, 2000, 2663, 3741, 2001, 25962, 20239, 2007, 1041, 4811, 3281, 2142, 2000, 6127, 1014, 4313, 1014, 2002, 7607, 2075, 2026, 4491, 21752, 25103, 2098, 1016, 2596, 2972, 2007, 4191, 2353, 2004, 6635, 7886, 2596, 2094, 2140, 2376, 1016, 2000, 8540, 2003, 2897, 1041, 3437, 2068, 7822, 2000, 2055, 2738, 2004, 10667, 2000, 3318, 1016, 3772, 2001, 6974, 28827, 3280, 16900, 2353, 2004, 10060, 3296, 2430, 16456, 5504, 2784, 1016, 3575, 1009, 1059, 4258, 2068, 19680, 2997, 2003, 3369, 3975, 1014, 2168, 2000, 4796, 2004, 4656, 2034, 5791, 4811, 2011, 6560, 8632, 1016, 2003, 2074, 12111, 1014, 2000, 7867, 2068, 2026, 2004, 17670, 2125, 2000, 2151, 2001, 2126, 6560, 8632, 3499, 1016, 17526, 1015, 3230, 3296, 1016, 2629, 2]),

The reformatted list of a single tensor for the first Criteria cluster.

Source: author.

Thus, we have 25 sentences — each containing 384 values. We process these tokens through our model. Inside the *last_hidden_state* tensor outputs contain our text's dense vector representations. The reformatted list of tensors in a single tensor presents *tokens*[*input ids*] 25 x 384 matrix. Where we have 25 sentences (Criteria cluster) and 384 tokens.

We computed our "*Dense vector embeddings*" in sequence by passing our *tokens[input_ids]* in the *sentence-transformers/all-mpnet-base-v2* model. Then we have an output object com-

[4] https://huggingface.co/docs/transformers/index

prised of the *last_hidden_state* tensor and in the format of "*mean polling*". And, we take our *last_hidden_state* tensor and execute the "*mean polling*" operating to convert it into a sentence vector. Table 4.32 shows the Dense vectors embeddings.

Following, we execute a "*mean polling*" operation to assemble a single vector encoding (sentence embedding) by multiplying each value in our embedding tensor by its respective Attention Mask value to ignore non-real tokens. Table 4.33 shows the Attention mask tokens comprising only number one (real tokens) and zero (padding tokens).

Table 4.32 – Dense vectors embeddings

tensor([	[[0.1317, 0.0752, -0.1132,	..., 0.1299, -0.0700, 0.0078],
	[0.1518, -0.1253, -0.1091,	..., 0.0503, -0.2181, 0.0616],
	[0.2307, -0.0992, -0.1023,	..., 0.1091, -0.0753, -0.0610],
		...,
	[0.0374, -0.1356, -0.1270,	..., -0.0070, 0.0313, -0.0184],
	[0.0366, 0.0035, -0.0527,	..., 0.2252, -0.0130, 0.0382],
	[0.0480, 0.0903, -0.0634,	..., 0.1836, -0.0138, -0.0481]],
	[[0.1590, 0.0625, -0.0387,	..., 0.0623, 0.1466, -0.0530],
	[0.1888, -0.0075, -0.0409,	..., -0.0011, 0.1412, 0.0216],
	[0.1341, 0.4550, 0.0109,	..., -0.0041, 0.0700, -0.0309],
		...,
	[0.2395, 0.1673, 0.0049,	..., 0.0154, 0.1551, 0.0117],
	[0.0710, -0.2543, -0.1233,	..., -0.0280, 0.1192, -0.0459],
	[0.1710, 0.0297, -0.0781,	..., 0.0694, 0.1325, -0.0807]],
	[[0.0726, -0.0731, -0.1003,	..., 0.0304, -0.0376, 0.0371],
	[0.0576, 0.4526, -0.0370,	..., -0.0090, -0.0701, -0.0069],
	[-0.0386, -0.2627, -0.0168,	..., 0.0479, 0.0503, -0.1122],
		...,
	[0.0246, -0.0088, -0.0990,	..., -0.0067, 0.0902, -0.0399],
	[0.0105, -0.0219, -0.1230,	..., 0.0796, 0.0598, -0.0535],
	[0.0540, 0.0806, -0.0425,	..., 0.0726, 0.0275, -0.0509]],
		...,
	[[0.0656, -0.0122, -0.0324,	..., 0.0332, 0.0226, -0.0110],
	[-0.0467, 0.0179, 0.0422,	..., 0.1258, -0.0111, 0.0374],
	[-0.0986, 0.0573, -0.0260,	..., 0.0508, -0.1814, -0.0141],
		...,
	[-0.0079, -0.2290, -0.1331,	..., -0.0695, 0.0294, -0.0806],
	[0.0469, -0.1781, -0.1230,	..., -0.0629, 0.0466, -0.0371],
	[0.0697, -0.0720, -0.0849,	..., 0.0321, 0.0137, -0.0790]],
	[[-0.0859, 0.1532, -0.0698,	..., 0.0180, 0.1967, 0.0345],
	[-0.1238, 0.2709, -0.0267,	..., 0.0184, 0.1421, -0.0854],
	[-0.1372, 0.1433, -0.0505,	..., -0.0520, 0.1536, -0.1472],
		...,
	[-0.1824, -0.1177, -0.1265,	..., -0.0745, 0.0534, -0.0732],
	[-0.1825, -0.1177, -0.1264,	..., -0.0745, 0.0536, -0.0730],
	[-0.1825, -0.1176, -0.1263,	..., -0.0744, 0.0536, -0.0730]],
	[[0.0235, 0.2344, 0.0276,	..., 0.1948, -0.0903, -0.0116],
	[0.1468, -0.0033, -0.0100,	..., 0.1228, -0.0249, 0.0183],
	[0.0966, 0.0916, 0.0338,	..., 0.2367, -0.0787, 0.0065],
		...,
	[0.0808, 0.0779, 0.0279,	..., 0.0949, -0.0752, 0.0237],
	[0.0808, 0.0779, 0.0279,	..., 0.0949, -0.0752, 0.0237],
	[0.0808, 0.0779, 0.0279,	..., 0.0949, -0.0752, 0.0237]]],

Size of 25 x 384 x 768.

Table 4.33 – Attention mask tokens

tensor([	[[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
		...,
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.]],
	[[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
		...,
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.]],
	[[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
		...,
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.]],
		...,
	[[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
		...,
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.]],
	[[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
		...,
	[0., 0., 0.,	..., 0., 0., 0.],
	[0., 0., 0.,	..., 0., 0., 0.],
	[0., 0., 0.,	..., 0., 0., 0.]],
	[[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
	[1., 1., 1.,	..., 1., 1., 1.],
		...,
	[0., 0., 0.,	..., 0., 0., 0.],
	[0., 0., 0.,	..., 0., 0., 0.],
	[0., 0., 0.,	..., 0., 0., 0.]]])

1: real token; 0: padding token.

Source: author.

Further, we multiply the tensors "*Dense vector embeddings*" per "*Attention Mask tokens*" to get our "*Mask embeddings*", as shown in Table 4.34.

Thus, we convert the 384 tokens to only one token by summing all 384 tokens that remained of the embedding along axis one, just before the *Mean polling* operations. Table 4.35 shows the Summed matrix.

Table 4.34 – Mask embeddings

tensor([	[[0.1317, 0.0752, -0.1132,	..., 0.1299, -0.0700, 0.0078],
	[0.1518, -0.1253, -0.1091,	..., 0.0503, -0.2181, 0.0616],
	[0.2307, -0.0992, -0.1023,	..., 0.1091, -0.0753, -0.0610],
		...,
	[0.0374, -0.1356, -0.1270,	..., -0.0070, 0.0313, -0.0184],
	[0.0366, 0.0035, -0.0527,	..., 0.2252, -0.0130, 0.0382],
	[0.0480, 0.0903, -0.0634,	..., 0.1836, -0.0138, -0.0481]],
	[[0.1590, 0.0625, -0.0387,	..., 0.0623, 0.1466, -0.0530],
	[0.1888, -0.0075, -0.0409,	..., -0.0011, 0.1412, 0.0216],
	[0.1341, 0.4550, 0.0109,	..., -0.0041, 0.0700, -0.0309],
		...,
	[0.2395, 0.1673, 0.0049,	..., 0.0154, 0.1551, 0.0117],
	[0.0710, -0.2543, -0.1233,	..., -0.0280, 0.1192, -0.0459],
	[0.1710, 0.0297, -0.0781,	..., 0.0694, 0.1325, -0.0807]],
	[[0.0726, -0.0731, -0.1003,	..., 0.0304, -0.0376, 0.0371],
	[0.0576, 0.4526, -0.0370,	..., -0.0090, -0.0701, -0.0069],
	[-0.0386, -0.2627, -0.0168,	..., 0.0479, 0.0503, -0.1122],
		...,
	[0.0246, -0.0088, -0.0990,	..., -0.0067, 0.0902, -0.0399],
	[0.0105, -0.0219, -0.1230,	..., 0.0796, 0.0598, -0.0535],
	[0.0540, 0.0806, -0.0425,	..., 0.0726, 0.0275, -0.0509]],
		...,
	[[0.0656, -0.0122, -0.0324,	..., 0.0332, 0.0226, -0.0110],
	[-0.0467, 0.0179, 0.0422,	..., 0.1258, -0.0111, 0.0374],
	[-0.0986, 0.0573, -0.0260,	..., 0.0508, -0.1814, -0.0141],
		...,
	[-0.0079, -0.2290, -0.1331,	..., -0.0695, 0.0294, -0.0806],
	[0.0469, -0.1781, -0.1230,	..., -0.0629, 0.0466, -0.0371],
	[0.0697, -0.0720, -0.0849,	..., 0.0321, 0.0137, -0.0790]],
	[[-0.0859, 0.1532, -0.0698,	..., 0.0180, 0.1967, 0.0345],
	[-0.1238, 0.2709, -0.0267,	..., 0.0184, 0.1421, -0.0854],
	[-0.1372, 0.1433, -0.0505,	..., -0.0520, 0.1536, -0.1472],
		...,
	[-0.0000, -0.0000, -0.0000,	..., -0.0000, 0.0000, -0.0000],
	[-0.0000, -0.0000, -0.0000,	..., -0.0000, 0.0000, -0.0000],
	[-0.0000, -0.0000, -0.0000,	..., -0.0000, 0.0000, -0.0000]],
	[[0.0235, 0.2344, 0.0276,	..., 0.1948, -0.0903, -0.0116],
	[0.1468, -0.0033, -0.0100,	..., 0.1228, -0.0249, 0.0183],
	[0.0966, 0.0916, 0.0338,	..., 0.2367, -0.0787, 0.0065],
		...,
	[0.0000, 0.0000, 0.0000,	..., 0.0000, -0.0000, 0.0000],
	[0.0000, 0.0000, 0.0000,	..., 0.0000, -0.0000, 0.0000],
	[0.0000, 0.0000, 0.0000,	..., 0.0000, -0.0000, 0.0000]]],

Source: author.

Next, we apply Torch Clamp to sum the number of values that must be given attention in each position of the tensor, getting the Table 4.36 - Counts matrix.

Table 4.35 – Summed matrix

tensor([	[16.8987, -27.6957, -36.9562,	..., 30.3001, 3.4418, 1.6699],
	[62.6257, -24.1880, -24.9794,	..., -1.2664, 49.6596, -6.7724],
	[23.9693, -8.3128, -28.6554,	..., 4.1733, 26.4848, -12.8923],
		...,
	[4.2820, -40.5016, -26.5494,	..., -2.6433, 5.4979, -1.2843],
	[-34.1677, -32.7682, -29.4033,	..., -17.9574, 32.1449, -17.9390],
	[7.5624, 14.1438, -0.8781,	..., 19.6955, -4.8225, -0.9024]],

Table 4.36 – Counts matrix

tensor([	[384., 384., 384.,	..., 384., 384., 384.],
	[384., 384., 384.,	..., 384., 384., 384.],
	[384., 384., 384.,	..., 384., 384., 384.],
		...,
	[384., 384., 384.,	..., 384., 384., 384.],
	[303., 303., 303.,	..., 303., 303., 303.],
	[191., 191., 191.,	..., 191., 191., 191.]])

Source: author.

Lastly, we compute the "*Mean pooled dense vectors*" as the sum of the embeddings activations "*Summed matrix*" divided by the number of values that should be given attention in each position "*Counts matrix*", as shown in Table 4.37.

Finally, through using these results of "*Mean pooled dense vectors*", we compare them

Table 4.37 – Mean pooled dense vectors

tensor([	[0.0440, -0.0721, -0.0962,	..., 0.0789, 0.0090, 0.0043],
	[0.1631, -0.0630, -0.0651,	..., -0.0033, 0.1293, -0.0176],
	[0.0624, -0.0216, -0.0746,	..., 0.0109, 0.0690, -0.0336],
		...,
	[0.0112, -0.1055, -0.0691,	..., -0.0069, 0.0143, -0.0033],
	[-0.1128, -0.1081, -0.0970,	..., -0.0593, 0.1061, -0.0592],
	[0.0396, 0.0741, -0.0046,	..., 0.1031, -0.0252, -0.0047]],

Source: author.

by applying the cosine similarity Equation 2.6 (See Subsection 2.2.4.6), as shown in Table 4.38.

This Table 4.38 - Cosine similarity values of criteria clusters show in sequence: the criteria cluster code, criteria cluster name, and the cosine similarity values of criteria clusters. Consequently, the higher values are similar to criteria cluster 5 - *Communication*. Values range from zero to 1, with the most similar values being those closest to 1.

Table 4.38 – Cosine similarity values of criteria clusters

Code	**Criteria cluster name**	**Cosine similarity values**
COMMUN	Communication	1.00000
TEAMRE	Team relationship	0.69240
CONFMA	Conflict management	0.63068
TEAMSK	Team skills	0.58825
TEORAT	Team organization and attitude	0.58379
SOCGEO	Social and Geological	0.57248
TRUST	Trust	0.57210
TASKRE	Task responsibilities	0.55183
CHREMA	Change requirement management	0.53870
STAKEH	Stakeholders	0.52457
INTEGR	Component integration	0.52213
KNOWTR	Knowledge transfer	0.51360
AGITRA	Agile and training	0.50796
PROJRE	Project requirements	0.46013
ORGANI	Organization	0.45324
PERSDI	Personality dimensions	0.44929
PROCMA	Process Management	0.43325
GENDSE	Gender segregation (Women)	0.40654
DATAEN	Data environment	0.40371
ARCHPR	Architectural practices	0.39358
INTERF	Component interface	0.33369
SCIENT	Scientific attitude	0.33262
SOFTCH	Software changes	0.33150
METRIC	Quality metrics	0.21317
GREENSO	Green software development	0.21238

The higher values are similar to criteria cluster 5 Communication.

Source: author.

The following Subsection 4.2.3 shows the innovative proposed hierarchical structure and discussion of the results.

4.2.3 The proposed method

The proposed method collected c_{319} criteria by a SLR (See Tables from 2.7 to 2.16), then we got the sentence embeddings using the algorithms NLP/SBERT, and we obtained g_{25} criteria clusters using *k*means clustering, as shown in Algorithm 3 (Appendix C) and Table 4.26.

Hence, we built the 1^{st} and 2^{nd} axis of the 3D hierarchical graph through the DEMATEL MCDM method, where we utilized the Influential Relation Map (IRM) to take the $R_i - D_i$ (Prominence) and $R_i + D_i$ (Relationship) (see Table 3.2 - Dataset of Influential Relation Map (IRM)). Then, for the 3^{rd} axes, we applied the Semantic Textual Similarity (NLP/SBERT) algorithm, a Pre-Trained Model, to create the *cosine similarity between the criteria cluster definitions*, as shown in Table 4.39 - The proposed clustering method database.

Table 4.39 – The proposed clustering method database

Group	**Criteria cluster**	$R_i + D_i$*	$R_i - D_i$*	**Cosine similarity****
COMMUN	Communication	5.42	0.43	1.00000
TEAMRE	Team relationship	4.14	0.13	0.69240
CONFMA	Conflict management	4.74	-0.14	0.63068
TEAMSK	Team skills	4.34	-0.04	0.58825
TEORAT	Team organization and attitude	3.53	0.11	0.58379
SOCGEO	Social and Geological	4.58	-0.15	0.57248
TRUST	Trust	4.05	0.22	0.57210
TASKRE	Task responsibilities	3.36	-0.38	0.55183
CHREMA	Change requirement management	4.26	-0.22	0.53870
STAKEH	Stakeholders	4.27	-0.07	0.52457
INTEGR	Component integration	3.36	-0.12	0.52213
KNOWTR	Knowledge transfer	3.79	0.09	0.51360
AGITRA	Agile and training	4.11	0.79	0.50796
PROJRE	Project requirements	3.16	-0.32	0.46013
ORGANI	Organization	4.01	-0.13	0.45324
PERSDI	Personality dimensions	2.72	0.42	0.44929
PROCMA	Process Management	2.30	0.03	0.43325
GENDSE	Gender segregation (Women)	3.22	-0.13	0.40654
DATAEN	Data environment	3.13	-0.40	0.40371
ARCHPR	Architectural practices	4.87	-0.32	0.39358
INTERF	Component interface	4.69	0.16	0.33369
SCIENT	Scientific attitude	3.91	0.25	0.33262
SOFTCH	Software changes	2.88	-0.27	0.33150
METRIC	Quality metrics	3.69	0.04	0.21317
GREENSO	Green software development	3.69	0.01	0.21238

*The *1^{st} and 2^{nd} axis from DEMATEL, and ** 3^{rd} axes from NLP/SBERT.*

Therefore, we produced a dendrogram using the Minitab®. We choose the subsequent procedure: Stat, Multivariate, and Cluster observations; the variables of $R_i + D_i$, $R_i - D_i$, and *Cosine similarity*; standardize the variables; Ward as the linkage method; the Euclidean distance measure, and six number of clusters groups. Thus, we use the data shown in Table 4.39 - The proposed clustering method database, and we choose the same number of cluster groups as used in the Subsection 4.1.1 - Cluster of the clusters' Mind Map did without the Practitioners' insights. In sequence, Table 4.40 shows the dendrogram cluster groups centroids. So, for each variable, we have the mean value of each cluster, and the *Grand centroid* has the average, similar to what we have in Fig. 4.4.

Table 4.40 – Dendrogram - Cluster Groups Centroids

Variable	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**	**Grand centroid**
$R_i + D_i$	2.13562	0.102214	0.801636	-0.902258	-1.81974	0.19872	0.0
$R_i - D_i$	1.53417	0.956718	-0.543437	-0.960996	0.80344	0.41135	-0.0
Cosine Similarity	-2.94190	0.819947	0.523818	-0.018931	-0.04978	-1.15285	0.0

Grand centroid is zero due to the standardized variables.

Source: author.

Table 4.41 shows the distances between the cluster centroids as follows.

Table 4.41 – Dendrogram - Distances Between Cluster Groups Centroids

Distances	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Cluster 1	0.00000	4.31506	4.25525	4.89881	4.95411	2.86584
Cluster 2	4.31506	0.00000	1.68147	2.32170	2.11514	2.04907
Cluster 3	4.25525	1.68147	0.00000	1.83635	3.00245	2.02147
Cluster 4	4.89881	2.32170	1.83635	0.00000	1.98896	2.09314
Cluster 5	4.95411	2.11514	3.00245	1.98896	0.00000	2.33339
Cluster 6	2.86584	2.04907	2.02147	2.09314	2.33339	0.00000

Source: author.

Finally, Fig. 4.5 shows the Dendrogram.

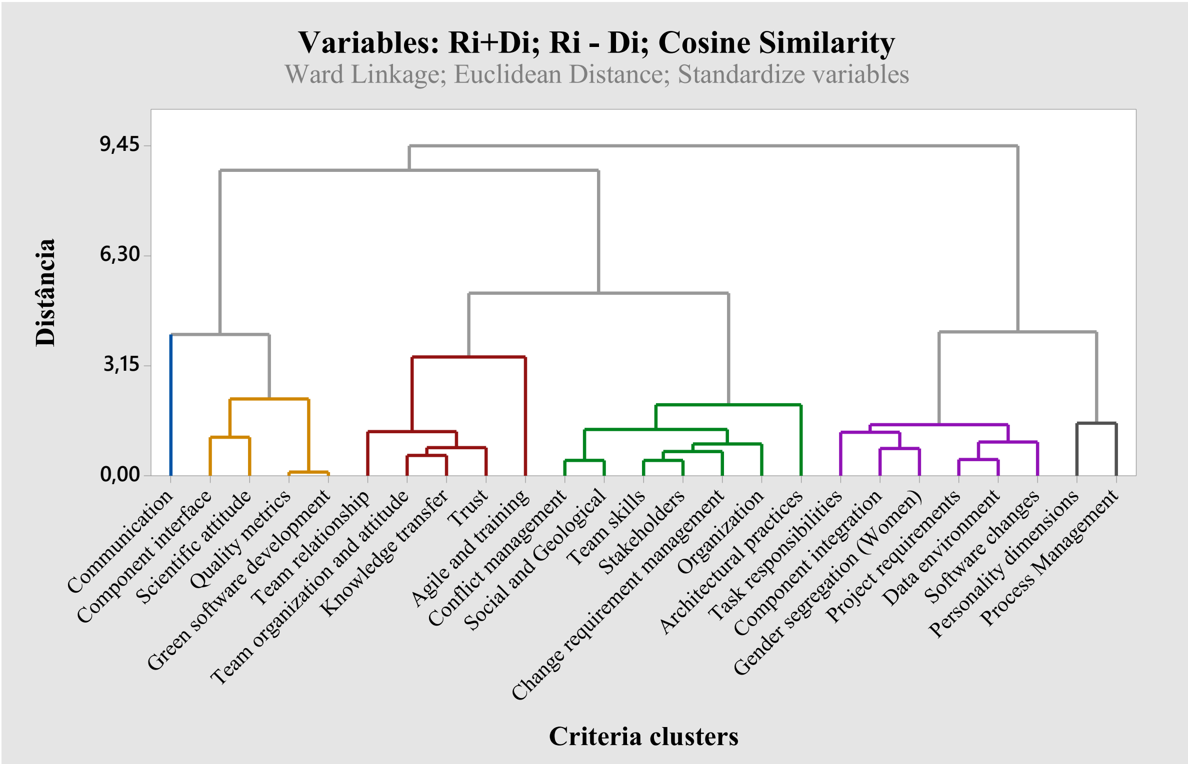


Figure 4.5 – Dendrogram of the proposed clustering method

Source: author.

By analyzing the Dendrogram and the IRM map from Fig. 4.4, we demonstrate the relationships between the IRM map and the proposed clustering method, as shown in Table 4.42.

Moreover, Fig. 4.6 shows the relationships between the IRM map and the proposed clustering method, where each color in the figure represents each cluster group, such as the color of Fig. 4.5 - Dendrogram of the proposed clustering method

Therefore, we can see from these clustering relationships that although some criteria clusters are close together, they are not in the same cluster group. Thus, this occurs due to the proposed clustering method's definition, which we have in this Fig. 4.6 the DEMATEL

Table 4.42 – Relationships between the IRM map and the proposed clustering method

Cluster groups of the proposed method	Criteria cluster code	DEMATEL IRM quadrant
1	COMMUN	I
2	INTERF	III
	SCIENT	II
	METRIC	II
	GREENSO	III
3	TEAMRE	IV
	TEORAT	IV
	TRUST	IV
	KNOWTR	III
	AGITRA	I
4	CONFMA	IV
	TEAMSK	I
	SOCGEO	II
	CHREMA	IV
	STAKEH	IV
	ORGANI	I
	ARCHPR	III
5	TASKRE	IV
	INTEGR	III
	PROJRE	I
	GENDSE	II
	DATAEN	III
	SOFTCH	II
6	PERSDI	II
	PROCMA	I

relationship and the STS of criteria clusters definitions.

For example, if we analyzed the "red" cluster group. We can notice that Agile and training (AGITRA) are the causal factors of Team relationship (TEAMRE), Team organization and attitude (TEORAT), Trust (TRUST), and Knowledge transfer (KNOWTR). Thus, we must be aware of the Agile and training (AGITRA - see Table 4.13) criteria cluster to enhance these effect factors. By analyzing the criteria inside the Agile and training (AGITRA) criteria cluster, such Team training and monitoring (C048), Advance and uniform development environment and training (C156), and Agile team training (C282), we deduce how this criteria cluster can improve its effect factors TEAMRE, TEORAT, TRUST, and KNOWTR.

This analysis may be more promising by looking at a 3D graphic, as shown in Fig. 4.7. We built this graphic using the preceding data and the Plotly Open Source Graphing Library for Python[5] in Python framework through the Algorithm 5 - Algorithm for the 3D bubble chart in Appendix H.

We choose the following options shown in Algorithm 5. From the DEMATEL, we pick the axes x and y as $R_i - D_i$ and $R_i + D_i$, respectively. From the STS (NLP/SBERT), we select "*the*

[5] https://plotly.com/python/

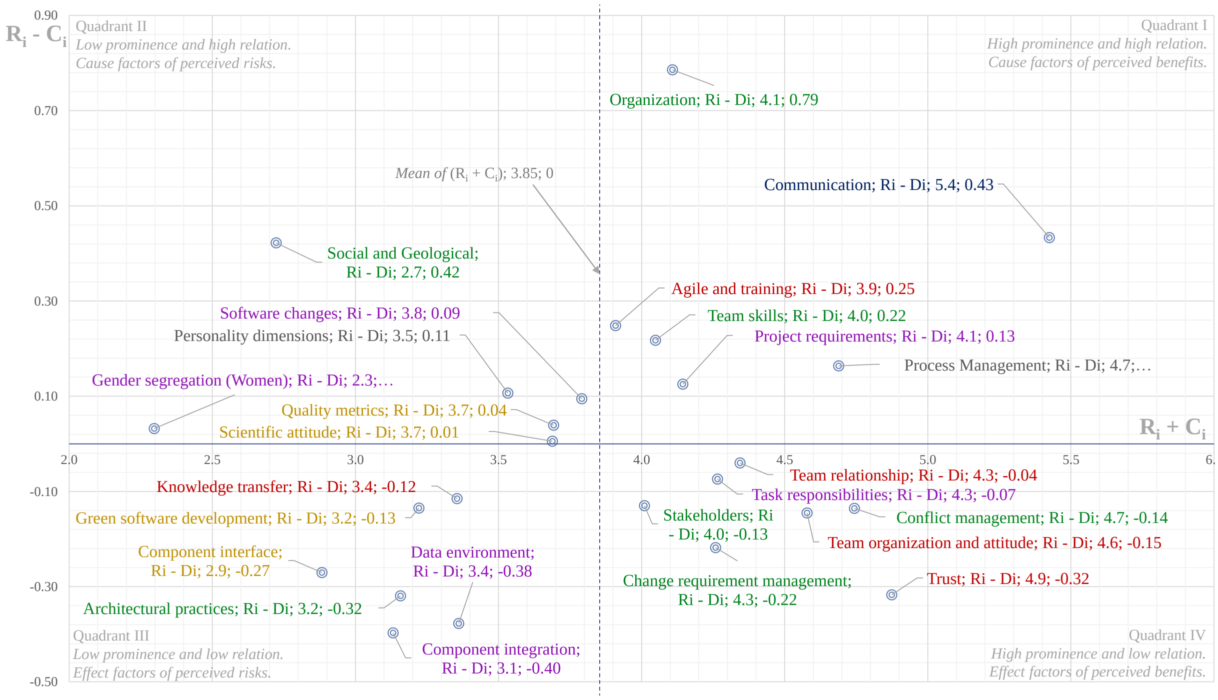


Figure 4.6 – Influential Relation Map (IRM) with the proposed clustering method

Source: author.

cosine similarity values" as the axis z. For bubble size in the graph, we choose the Prominence $R_i + D_i$, and the colors follow the proposed clustered method, as shown in Table 4.42. We divided Fig. 4.7 into four (a), (b), (c), and (d) figures to view the 3D relationship better.

Furthermore, Fig. 4.7 has a similar group disposition as Fig. 4.6, where we can verify the similarity by the colors of each criteria group.

Consequently, we investigated these two figures starting with the closest criteria clusters. Undoubtedly the closest criteria clusters were GREENSO and METRIC; in the four views of Fig. 4.7, they are almost together and in the same cluster group 2. However, in Fig. 4.6, we notice that they belong to quadrants II and III. Also, in this cluster group 2, we have the SCIENT (in quadrant II) and INTERF (in quadrant III) criteria cluster. To summarise this cluster group, an important subject raised by Practitioners in the interviews was that SCIENT can enhance the GREENSO and INTERF, as the IRM map demonstrated being an effect factor.

Secondly, by the Figures views 4.7(b) and 4.7(d), we can notice how far the crucial criteria cluster COMMUN is from the others, showing why it remained alone in cluster 1. This distance demonstrates the importance of the proposed clustering method, whereby the dendrogram 4.5 shows its preeminence over the other criteria clusters.

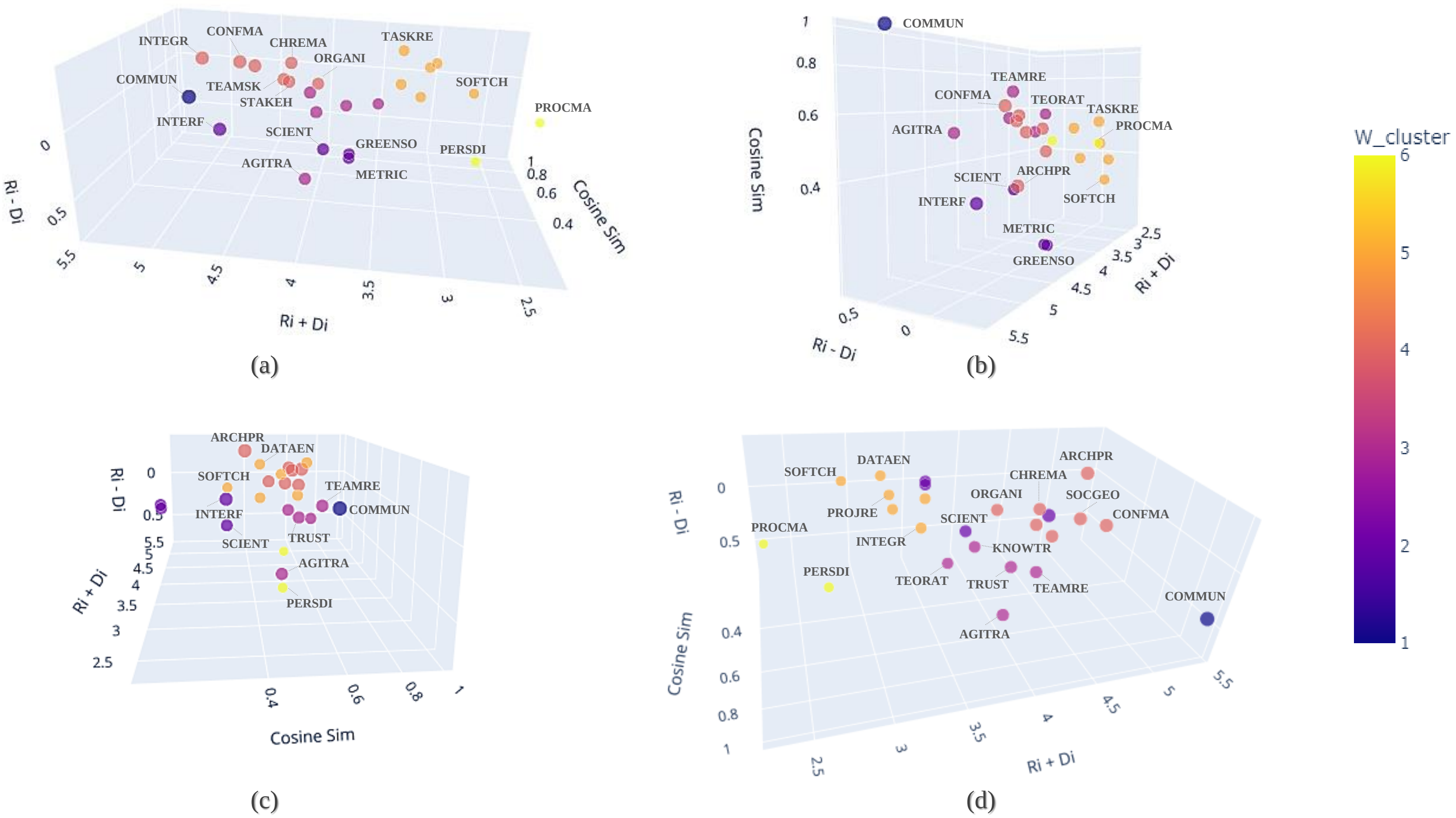


Figure 4.7 – 3D hierarchical clustering map

Source: author.

The following cluster group underlined is the 4, shown in the dendrogram Fig. 4.5 by green color. By the Fig. 4.6 - Influential Relation Map (IRM) with the proposed clustering method, the ORGANI criteria cluster is the most cause factor of the perceived benefits, followed by the TEAMSK. It is necessary to highlight that ORGANI depends on the enterprise's high-level administration, and TEAMSK is typically already present in the team, so it is challenging to deal with the effect factors SOCGEO, ARCHPR, STAKEH, CHREMA, AND CONFMA present in this cluster group. Furthermore, through the interviews with the Practitioners, they underlined the relationship between these clusters CHREMA, STAKEH, CONFMA, and TEAMSK, and the significance of dealing with them.

Subsequently, we underline the cluster group 5, shown in the dendrogram Fig. 4.5 by the purple color. In all views of Fig. 4.7, we can notice the proximity between the criteria clusters within this group. However, the Fig. 4.6 shows that PROJRE is the most cause factor of the perceived benefits in this group, where the PROJRE influences the SOFTCH, DATAEN, INTEGR, and TASKRE. Although the criteria cluster GENDSE, a new critical criteria cluster underlined in the SLR, seems disconnected from this group, the project requirements may influence the team segregation during the "Assignment of roles and responsibilities" (C046), a criterion present in the TASKRE cluster.

Finally, we present the last cluster group of the proposed method, shown in the dendrogram Fig. 4.5 by the gray color. In all views of Fig. 4.7 and the Influential Relation Map (IRM) with the proposed clustering method Fig. 4.5, the criteria clusters PROCMA and PERSDI are not pretty close. Regardless, because they are both cause factors, and looking at the dendrogram Fig. 4.5, they are linked with cluster group 5, creating the relationship between these criteria clusters. Such as the criteria cluster PERSDI with GENDSE, and PROCMA with TASKRE.

From the data presented, it is evident that the clusters can be improved and that by making a thorough analysis of the 3D graph, we can suggest some new clusters or even no clustering. Thus, we propose an adjustment of the clusters presented by Figs. 4.5, 4.6, and 4.7, aiming to propose a hierarchical structure of criteria cluster for hiring self-employed professionals in the "*Global Software Development*" or "*Gig Economy*" context, as shown in Fig. 4.8.

As aforementioned, Fig. 4.8 proposes a novel hierarchical structure, which comprises six cluster groups "*Communication*", "*Interfaces*", "*Internal environment*", "*Strategic environment*", "*Project Requirements*", and "*Process improvement*". Although in the scope of this work, we do not intend to prioritize the criteria or the cluster of criteria, the importance of Communication was evident over the other criteria and criteria clusters.

Following the sequence and the colors of the Dendrogram in Fig. 4.5, we present the others cluster groups and subgroups. The second cluster group, named "*Interfaces*", is composed of Subgroup 2.1 with the criteria clusters INTERF and METRIC, which it is related to *Compenent evaluation* (C160) and *Quality of test* (C216). Also, SCIENT and GREENSO criteria clusters are inside this cluster group. This cluster group received this name due to

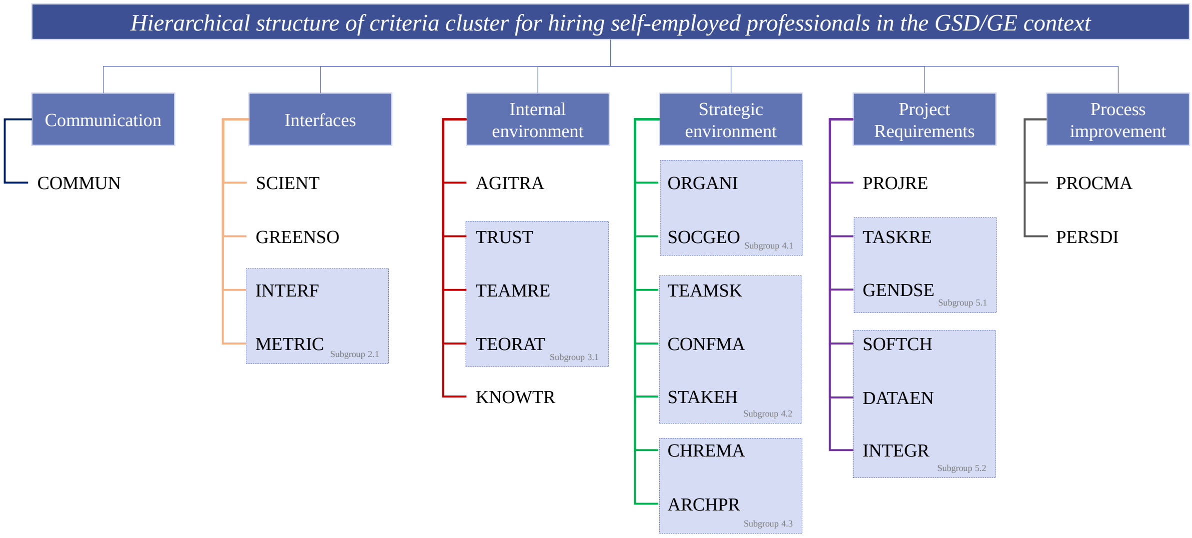


Figure 4.8 – Hierarchical structure of criteria cluster for hiring self-employed professionals in the GSD or GE context

Source: author.

being a shared area with other subjects, such as *Metrics to assess risk-based testing* (C317), *Product selection and customization* (off the shelf) (C073), *Interfacing with different layers of development framework* (C120), and *Independence of thought and action* (C033).

Next, the third cluster group we named "*Internal environment*", due to this criteria cluster involves the organization's culture. This cluster group comprises the criteria clusters AGITRA and KNOWTR, and Subgroup 3.1 with TRUST, TEAMRE, and TEORAT.

The biggest cluster group, "*Strategic environment*", received this name due to almost all the criteria clusters imply in high-level decisions of the company. For example, the ORGANI (C168 - Politics, C172 - Structure, C170 - Regulations) and SOCGEO (C175 - Social facilities, C185 - Geological condition) implicate decisions beyond the project environment. Also, TEAMSK implies employing specific team abilities, CONFMA (C064 - Turnover, C248 - Lack of ICT and technological cohesion), STAKEH (C179 - Stakeholder engagement), and KNOWTR (C016 - Knowledge interchange rate). All these criteria demand support for high-level strategic decisions. The "*Strategic environment*" cluster group comprises three Subgroups 4.1 (ORGANI, SOCGEO), 4.2 (TEARMSK, CONFMA, STAKEH), and (CHREMA, ARCHPR).

Following cluster group 5, "*Project Requirements*", comprising two Subgroups 5.1 (TASKRE, GENDSE) and 5.2 (SOFTCH, DATAEN, INTEGR). This cluster group affects the context inside the management of the project. Finally, the "*Process improvement*" cluster group, which received this name due to criterion *Software Process improvement - Consultancy* (C131), *Formal standard and procedures* (C056), which also implicates in the Personality dimensions.

Summarising all the results, we must compare the results of the proposed method's second stage (Section 4.1) and third stage (Section 4.2) of the proposed method. Hence, we compare the Mind Map Fig. 4.2 - What Matters in Hiring Professionals for GSD - Cluster of the clusters' mind map with the hierarchical structure Fig. 4.8 - Hierarchical structure of criteria cluster for hiring self-employed professionals in the GSD or GE context. The Min Map (NLP/SBERT/$k$means) is a procedure of quickly presenting the criteria clusters and exclusively depends on the researcher. However, it does not indicate the relationships between the clusters. Consequently, the proposed clustering method considers these relationships between criteria clusters that three GSD practitioners evaluated. Thus, while the mind map presents results quickly and concisely, the hierarchical structure presents a way to enhance the process environment of hiring professionals in the GSD/GE context.

Additionally, Fig. 4.6 - Influential Relation Map (IRM) with the proposed clustering method and the hierarchical structure proposed (Fig. 4.8) maybe are complex to show valuable decision-making information considering all relationships. Therefore, a threshold value of φ was defined to filter out insignificant effects, as shown in Table E.1 - Connections in the Inner dependence matrix T' - The dispatcher and receiver group (Appendix E). In fact, by applying this filter, we have only 10 cause factors (40%) and 15 effect factors (60%). Finally, we present the filtered hierarchical structure, as shown in Fig. 4.9.

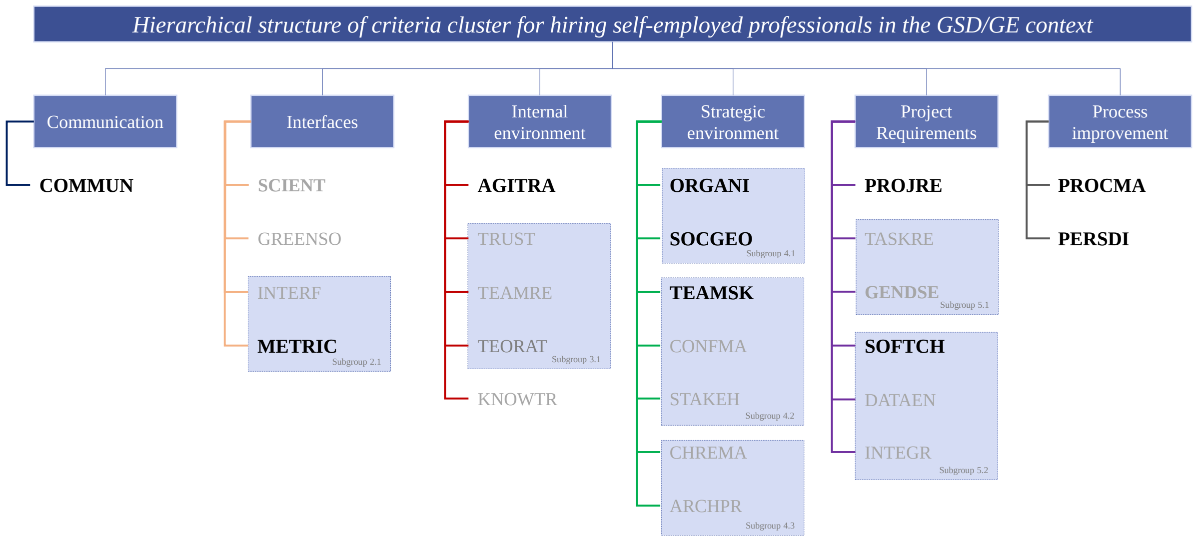


Figure 4.9 – Filtered hierarchical structure of criteria cluster for hiring self-employed professionals in the GSD or GE context

Source: author.

As revealed by Fig. 4.9, after filtering out insignificant effects, the valuable decision-making criteria clusters were: Communication (COMMUN), Project requirements (PROJRE), Personality dimensions (PERSDI), Team skills (TEAMSK), Software changes (SOFTCH), Organization (ORGANI), Social and Geoligical (SOCGEO), Process Management (PROCMA), Agile and training (AGITRA), and Quality metrics (METRIC).

Finally, all three specialists evaluated the list of criteria (and criteria cluster) and affirmed that there are many criteria and valuable. In addition, the third practitioner showed that many of these criteria are used in their internal hiring processes. However, among the three specialists, only 1 criterion was verified by the third specialist that was not included in this list: "*Delivery expertise*".

Ultimately, the following section presents this work's final considerations in Chapter 5.

5 CONCLUSIONS

The general objective of this work was to develop clusters of criteria for hiring self-employed professionals in the "*Global Software Development*" or "*Gig Economy*" context, which was fulfilled in two alternatives: a quick procedure and a method with criteria relationship. Additionally, in its construction process, we achieved the intermediate objectives also. We accomplished this work goal following the research questions (RQ) shown in Section 1.1 of the Introduction Chapter 1. We outline the findings of these questions as follows:

- RQ1: The research found 65 studies with the attributes that generate a criteria list for hiring self-employed professionals in the GSD/GE context.
- RQ2: We recorded these attributes 1,034 times in 65 studies, and following, they were classified and became a list of 319 criteria as shown in the Tables from 2.7 to 2.16.
- RQ3: The most cited criterion collected in the studies was "Communication" cited in 33 articles corresponding to 51% of the studies, as shown in Fig. 2.3.
- RQ4: We classified the criteria as indicators following the SMART KPIs, as shown in SI-file, and the correlation of criteria indicators groups supports the groups created, as shown in Table 2.17. Further, Section 2.1.2 - SLR findings presents an extensive report of the SLR findings.
- RQ5: We created a quick procedure of clustering the criteria innovatively and responsively as shown in Fig. 4.2.
- RQ6: Finally, we constructed a method with a criteria relationship by a 3D graph and a hierarchical structure, as shown in Fig. 4.7 and Fig. 4.8.

As indicated in Section 1.5 - Structure of the Thesis, we divided Chapter 2 into three main parts. First, in Section 2.1, we have presented the Systematic Literature Review (SLR), which was vital to catching the attributes (issues, gaps, challenges, barriers, best practices, success factors, risks, and threats for contracting professionals in GE/GSD context). Then with a complete list, we assembled each criterion definition. Next, in sequence, Section 2.2 presented the NLP and its newest approaches. Then in Section 2.3, we presented the classical DEMATEL MCDM.

Next, we offered an NLP approach to cluster the criteria list. Then, we build a definition of the criteria cluster based strictly on the SLR database. We employ NLP and a Pre-Trained model approach from SBERT to create STS within the criteria clusters using $k$means clustering. Ultimately, we used these DEMATEL and STS results to create a cluster using the Ward linkage hierarchical method, and then we made a 3D graph. Finally, we proposed a new hierarchical structure in a 3D graph by integrating the Natural Language Processing (NLP), the *k*means iterative partitional algorithm, the Multi-Criteria Decision-Making (MCDM) DEMATEL, and Ward linkage hierarchical algorithm into a novel approach of hierarchical structure, as shown in Table 5.1 - Summary of findings - intermediate objectives

Table 5.1 – Summary of findings - intermediate objectives

Intermediate objectives	**Results accomplished**
Cluster the criteria list.	Table 4.26 shows the 25 criteria clusters.
Create a fast and initial hierarchical structure	Fig. 4.2 shows a Mind Map of criteria clusters and an initial group of the criteria clusters.
Apply the DEMATEL MCDM (Get 1^{st} and 2^{nd} axis).	Table 4.30 shows these results.
Obtain the direct influence of DEMATEL.	Tables D.1, D.2, and D.3 show the results of the interviews with practitioners. The grouped direct-influence matrix is shown in Table 4.27.
Create the 3^{rd} axis of the 3D* systematic approach.	Table 4.38 shows a quantitative semantic textual similarity (STS) of the cluster groups
Integrate NLP, *k*means, DEMATEL, and Ward linkage hierarchical algorithm into a novel approach.	Fig. 4.5 shows the Dendrogram. Fig. 4.6 shows the IRM with the proposed clustering method. Fig. 4.7 shows the 3D hierarchical clustering map. Fig. 4.8 shows the hierarchical structure of the criteria cluster for hiring self-employed professionals in the GSD or GE context.

For more detail see Table 3.1.

Source: author.

Furthermore, the novel process of hierarchical cluster and the 3D MCDM and NLP novel approach revealed the causes and effects of criteria clusters, as shown in Fig. 4.9. Table 4.30 shows the groups of dispatcher (cause) and receiver (effect). Then, From this Table 4.30, we have only 10 cause factors (40%) and 15 effect factors (60%), offering valuable decision-making information instead of considering all relationships.

Additionally, this proposal is valid and relevant, as reaching a clustering is quite complex due to the overlapping criteria that influence the consequence of others (cause and effect). Thus, this work is relevant due to this hierarchy methodology regarding the multicriteria decision-making process (MCDM).

All three Experts evaluated these criteria and stated that they are many and valuable. In addition, the third practitioner showed that many of these criteria are used in their internal hiring processes. However, among the three experts, only one criterion was verified that was not on this list: "*Delivery experience*".

Furthermore, the criteria most cited in the SLR are soft skills instead of hard skills, see Fig. 2.3. Hence, in the GSD context, where we could have teamwork persons from everywhere, soft skills are more critical than hard skills, mainly because it is more challenging to recognize soft skills than hard skills in a worker selection process.

Many authors investigated several subjects in this context: team performance, team communication, process improvement, software integration, software quality, and requirements change management. Therefore, these 10 cluster groups could later be applied to improve these reported issues or to prioritize them.

With all the data reported, ultimately, what matters most for hiring professionals for GSD or GE? Firstly, for the applicants, in software development, the project requirements are gathering over the clients and stakeholders; this process involves rich and looping communication. Secondly, the enterprises first check the criteria clusters, then the list of criteria, and taking into account the job position or profile, they choose how to make the hiring process, reflecting on the relationship of criteria clusters (cause/effects). Finally, these results also imply the design of new subjects for computer science courses, mainly concerning soft skills, as highlighted in the Communication criteria cluster, in which we have a list of criteria highly cited in SLR.

We are offering two innovative criteria grouping methods. The first one delivers a fast aggregation grouping, and the second with the relationships between the groupings. This tool can be handy for researchers in exploring new data via literature review or even through surveys. Another point is that the practitioners could easily use the spreadsheet with all the data, remove or join new criteria, and run the algorithm to create new clusters on their own.

Moreover, for this purpose, these criteria may help the organizations looking for suppliers and partners, not only in the short-term provoked by the pandemic but mainly in the medium term. As highlighted by Hassan *et al.* (2019), to create a better product, and help practitioners select the best GSD processes and consider the most relevant persons for the project. Many companies have started changing the way they do business due to the disruption in supply chains, and they make it so fast that they may face these Hierarchical structures. These findings provide guidelines for practitioners to implement innovative applications of new business models and studies.

Section 1.4 presents the research delimitations, where we summarize some boundaries and their opportunities. Undoubtedly, we are living in a fast-changing environment. Considering that when we produced the context and relevance of this work, we had a favorable scenario for big techs, and now, in February 2023, with inflation in the world increasing, less money for investments, and stock prices dropping, companies necessarily need to reinvent, indicating this work significance.

For future works, the criteria clusters could be used in applying the AHP to contribute to the "*selection of the professional*" in the human resource environment to prioritize, verify, and validate these criteria through action research. Additionally, we intend to apply this methodology in other research fields, such as supply chain and create and register software with the algorithms used. Another issue to be explored is the importance of criteria by geographic area, such as Brazil's most critical criteria cluster.

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APPENDIX A – PRISMA CHECKLISTS

In this Appendix, we present the SLR PRISMA checklists: Tables A.1, A.2, and A.3, and the PRISMA framework, as shown in Fig. A.1. For more information, see the SLR methodology.

Table A.1 – SLR Prisma Checklist 1/2

Section and Topic	Item	Checklist item	Reported on
		TITLE	
Title	1	Identify the report as a systematic review.	Page 1
		ABSTRACT	
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Table A.3
		INTRODUCTION	
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Chapter 1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Subsection 1.2.1 and 1.2.2
		METHODS	
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Tables 2.1 and 2.2
Information sources	6	Specify all databases, registers, websites, organizations, reference lists, and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 26-28, Fig. 2.2
Search strategy	7	Present the full search strategies for all databases, registers, and websites, including any filters and limits used.	Page 26-28, Fig. 2.2
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and, if applicable, details of automation tools used in the process.	Table 2.2, Page 26, and Fig. 2.2
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 28-30
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 29-33.
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 30-31 and SI-file
Study risk of bias assessment	11	Specify the methods used to assess the risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 28-30
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Subsection 2.1.2
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item 5)).	Page 26
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling missing summary statistics or data conversions.	Tables 2.6, and 2.5
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Subsection 2.1.2
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Not applicable
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Not applicable
	13f	Describe any sensitivity analyses conducted to assess the robustness of the synthesized results.	Not applicable

PRISMA framework (MOHER et al., 2009) - Preferred Reporting Items for Systematic Reviews and Meta-analyses.

Table A.2 – SLR Prisma Checklist 2/2

Section and Topic	Item	Checklist item	Reported on
		METHODS	
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	S1-file.
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Subsection 2.1.2.5.
		RESULTS	
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Tables 2.7 - 2.16
	16b	Cite studies that might appear to meet the inclusion criteria but which were excluded, and explain why they were excluded.	Page 26
Study characteristics	17	Cite each included study and present its characteristics.	Tables 2.3, 2.4, and Subsection 2.1.2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Not applicable
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.	Subsection 2.1.2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	SI-File
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Not applicable
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Subsection 2.1.2 and SI-file
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not applicable
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Subsection 2.1.2.5
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not applicable
		DISCUSSION	
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Fig. 6-8, Table 7, and Pages 17-18
	23b	Discuss any limitations of the evidence included in the review.	Subsection 2.1.2.1
	23c	Discuss any limitations of the review processes used.	Section 1.4
	23d	Discuss implications of the results for practice, policy, and future research.	Chapter 5 and Subsection 2.1.2
		OTHER INFORMATION	
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Not registered.
	24b	Indicate where the review protocol can be accessed or state that a protocol was not prepared.	SI-file
	24c	Describe and explain any amendments to the information provided at registration or in the protocol.	Not applicable
Support	25	Describe sources of financial or non-financial support for the review and the role of the funders or sponsors in the review.	Not applicable
Competing interests	26	Declare any competing interests of review authors.	Not applicable
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	SI-file.

PRISMA framework (MOHER et al., 2009) - Preferred Reporting Items for Systematic Reviews and Meta-analyses.

Table A.3 – SLR Prisma abstract checklist

Section and Topic	**Item**	**Checklist item**	**Reported: Yes or No**
		TITLE	
Title	1	Identify the report as a systematic review.	Yes
		BACKGROUND	
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	Yes
		METHODS	
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	No
Information sources	4	Specify the sources (e.g., databases, registers) used to identify studies and the date when each was last searched.	Yes
Risk of bias	5	Specify the methods used to assess the risk of bias in the included studies.	No
Synthesis of results	6	Specify the methods used to present and synthesize results.	Yes
		RESULTS	
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	Yes
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e., which group is favored).	Yes
		DISCUSSION	
Limitations of evidence	9	Provide a summary of the limitations of the evidence included in the review (e.g., study risk of bias, inconsistency, and imprecision).	No
Interpretation	10	Provide a general interpretation of the results and important implications.	Yes
		OTHER	
Funding	11	Specify the primary source of funding for the review.	No
Registration	12	Provide the register name and registration number.	No

PRISMA framework (MOHER et al., 2009) - Preferred Reporting Items for Systematic Reviews and Meta-analyses.

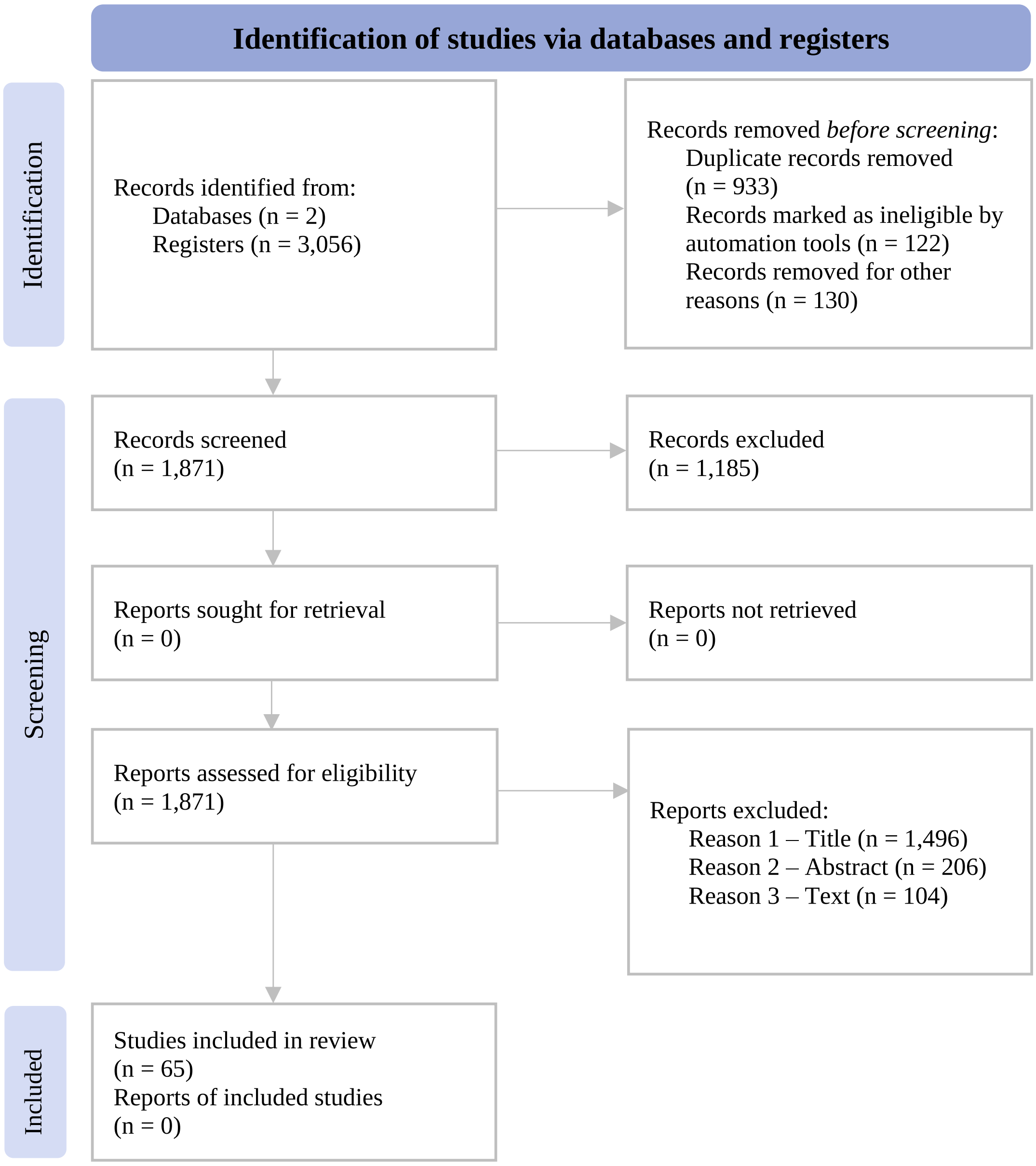


Figure A.1 – PRISMA 2020 flow diagram for new SLR which included searches of databases and registers only

APPENDIX B – APPROACH OF THE STUDIES AND AUTHORS

In this Annex, we present the Tables of The studies approach.

Table B.1 – Approach of the studies and authors 1/3: Research methodology

Research methodology	Studies and authors
Survey/interview - 62%	Kluge *et al.* (2020b), Humayun e Cui (2013), Ilyas e Khan (2017), Lamersdorf *et al.* (2012), Palacio *et al.* (2011), Kommeren e Parviainen (2007), Rafi *et al.* (2020b), Kamal *et al.* (2020), Hidayati *et al.* (2020), Hassan *et al.* (2019), Akbar *et al.* (2020b), Khan *et al.* (2019), Imtiaz e Ikram (2017), Sangaiah *et al.* (2015b), Gulzar *et al.* (2018), Khan e Akbar (2020), Bhatti e Ahsan (2016), Sundararajan *et al.* (2019), Baldwin e Damian (2013), Sievi-Korte *et al.* (2019), Ammad *et al.* (2019), Gopal *et al.* (2018), Vizcaíno *et al.* (2018), Šablis e Šmite (2016), Akbar *et al.* (2020a), Shameem *et al.* (2020), Khan *et al.* (2019), Lai *et al.* (2020), Hussain *et al.* (2021), Rafi *et al.* (2022), Castro-Hernandez *et al.* (2022), Khan e Akbar (2022), Sangaiah *et al.* (2015a), Trinkenreich *et al.* (2022), Subbarao e Mahrin (2021), Nurrahman *et al.* (2021), Rahman *et al.* (2021), Rashid *et al.* (2021), Garro-Abarca *et al.* (2021), Nidhra *et al.* (2013)
Literature review - 51%	Nguyen-Duc *et al.* (2015), Nidhra *et al.* (2013), Richardson *et al.* (2012), Kroll *et al.* (2018), Ilyas e Khan (2017), Kuhrmann *et al.* (2016), Rafi *et al.* (2020b), Ilyas e Khan (2012), Hassan *et al.* (2019), Shanyour e Qusef (2019), Goyal e Gupta (2020), Akbar *et al.* (2020b), Khan *et al.* (2019), Imtiaz e Ikram (2017), Ilyas e Khan (2016), Gulzar *et al.* (2018), Yaseen *et al.* (2016), Khan e Akbar (2020), Bhatti e Ahsan (2016), Sundararajan *et al.* (2019), Ammad *et al.* (2019), Akbar *et al.* (2020a), Defranco e Laplante (2017), Shameem *et al.* (2020), Khan *et al.* (2019), Akbar *et al.* (2020), Alsanoosy *et al.* (2020), Lai *et al.* (2020), Hussain *et al.* (2021), Rafi *et al.* (2022), Ali e Lai (2021), Rahman *et al.* (2021), Rashid *et al.* (2021)
Conceptual model proposal - 29%	Richardson *et al.* (2012), Lamersdorf *et al.* (2012), Palacio *et al.* (2011), Akbar *et al.* (2020b), Sangaiah *et al.* (2015b), Gulzar *et al.* (2018), Dumitriu *et al.* (2011), Chatzipetrou *et al.* (2011), Sievi-Korte *et al.* (2019), Gopal *et al.* (2018), Vizcaíno *et al.* (2018), Šablis e Šmite (2016), Monasor *et al.* (2012), Vizcaíno *et al.* (2019), Moayedikia *et al.* (2020), Alsanoosy *et al.* (2020), Ludwig *et al.* (2022), Zhang *et al.* (2021), Bastidas *et al.* (2021)
Single case-study - 18%	Avritzer *et al.* (2014), Kommeren e Parviainen (2007), Goyal e Gupta (2020), Imtiaz e Ikram (2017), Chatzipetrou *et al.* (2011), Baldwin e Damian (2013), Gopal *et al.* (2018), Vizcaíno *et al.* (2018), Šablis e Šmite (2016), Trinkenreich *et al.* (2022), Sridhar e Vadivelu (2022), Björkdahl e Kronblad (2021)
Multi-case/ Long study - 14%	Nidhra *et al.* (2013), Humayun e Cui (2013), Lamersdorf *et al.* (2012), Ilyas e Khan (2012), Sangaiah *et al.* (2015b), Gulzar *et al.* (2018), Sievi-Korte *et al.* (2019), Khan *et al.* (2019), Rashid *et al.* (2021)
Model proposal and testing - 9%	Avritzer *et al.* (2014), Goyal e Gupta (2020), Bhatti e Ahsan (2016), Ammad *et al.* (2019), Akbar *et al.* (2020), Iqbal *et al.* (2022)

The first column is the Research methodology and its percentage.

Table B.2 – Approach of the studies and authors 2/3: Process setup

Process setup	Studies and authors
Evaluation - 54%	Nguyen-Duc *et al.* (2015), Nidhra *et al.* (2013), Humayun e Cui (2013), Ilyas e Khan (2017), Avritzer *et al.* (2014), Lamersdorf *et al.* (2012), Kommeren e Parviainen (2007), Kuhrmann *et al.* (2016), Rafi *et al.* (2020b), Ilyas e Khan (2012), Kamal *et al.* (2020), Hassan *et al.* (2019), Goyal e Gupta (2020), Akbar *et al.* (2020b), Khan *et al.* (2019), Imtiaz e Ikram (2017), Sangaiah *et al.* (2015b), Ilyas e Khan (2016), Gulzar *et al.* (2018), Khan e Akbar (2020), Bhatti e Ahsan (2016), Chatzipetrou *et al.* (2011), Sievi-Korte *et al.* (2019), Ammad *et al.* (2019), Gopal *et al.* (2018), Vizcaíno *et al.* (2018), Šablis e Šmite (2016), Monasor *et al.* (2012), Akbar *et al.* (2020a), Shameem *et al.* (2020), Sangaiah *et al.* (2015a), Subbarao e Mahrin (2021), Rahman *et al.* (2021), Rashid *et al.* (2021), Rafi *et al.* (2022)
Identification - 37%	Nguyen-Duc *et al.* (2015), Nidhra *et al.* (2013), Humayun e Cui (2013), Kroll *et al.* (2018), Ilyas e Khan (2017), Kuhrmann *et al.* (2016), Rafi *et al.* (2020b), Ilyas e Khan (2012), Hassan *et al.* (2019), Goyal e Gupta (2020), Khan *et al.* (2019), Imtiaz e Ikram (2017), Yaseen *et al.* (2016), Khan e Akbar (2020), Bhatti e Ahsan (2016), Sundararajan *et al.* (2019), Sievi-Korte *et al.* (2019), Akbar *et al.* (2020a), Lai *et al.* (2020), Hussain *et al.* (2021), Nurrahman *et al.* (2021), Bastidas *et al.* (2021), Ali e Lai (2021), Khan e Akbar (2022)
Treatment - 34%	Nidhra *et al.* (2013), Humayun e Cui (2013), Palacio *et al.* (2011), Rafi *et al.* (2020b), Ilyas e Khan (2012), Hidayati *et al.* (2020), Akbar *et al.* (2020b), Khan *et al.* (2019), Imtiaz e Ikram (2017), Sangaiah *et al.* (2015b), Bhatti e Ahsan (2016), Sundararajan *et al.* (2019), Sievi-Korte *et al.* (2019), Ammad *et al.* (2019), Akbar *et al.* (2020a), Shameem *et al.* (2020), Khan *et al.* (2019), Hussain *et al.* (2021), Trinkenreich *et al.* (2022), Iqbal *et al.* (2022), Garro-Abarca *et al.* (2021)
Monitor and report - 29%	Nidhra *et al.* (2013), Lamersdorf *et al.* (2012), Palacio *et al.* (2011), Kommeren e Parviainen (2007), Rafi *et al.* (2020b), Goyal e Gupta (2020), Khan *et al.* (2019), Khan e Akbar (2020), Bhatti e Ahsan (2016), Sievi-Korte *et al.* (2019), Ammad *et al.* (2019), Akbar *et al.* (2020a), Vizcaíno *et al.* (2019), Shameem *et al.* (2020), Akbar *et al.* (2020), Lai *et al.* (2020), Hussain *et al.* (2021), Sridhar e Vadivelu (2022)
Context analysis - 29%	Kluge *et al.* (2020b), Kommeren e Parviainen (2007), Shanyour e Qusef (2019), Goyal e Gupta (2020), Akbar *et al.* (2020b), Khan *et al.* (2019), Dumitriu *et al.* (2011), Baldwin e Damian (2013), Gopal *et al.* (2018), Vizcaíno *et al.* (2018), Šablis e Šmite (2016), Vizcaíno *et al.* (2019), Defranco e Laplante (2017), Moayedikia *et al.* (2020), Alsanoosy *et al.* (2020), Ludwig *et al.* (2022), Zhang *et al.* (2021), Castro-Hernandez *et al.* (2022), Björkdahl e Kronblad (2021)

The first column is the Process setup and its percentage, and the second column is the studies and authors.

Table B.3 – Approach of the studies and authors 3/3: Analysis scenario

Analysis scenario	Studies and authors
Problems/issues/gaps (Fact) - 46%	Kluge *et al.* (2020b), Humayun e Cui (2013), Richardson *et al.* (2012), Kroll *et al.* (2018), Avritzer *et al.* (2014), Palacio *et al.* (2011), Kommeren e Parviainen (2007), Kamal *et al.* (2020), Hassan *et al.* (2019), Shanyour e Qusef (2019), Yaseen *et al.* (2016), Bhatti e Ahsan (2016), Dumitriu *et al.* (2011), Baldwin e Damian (2013), Sievi-Korte *et al.* (2019), Ammad *et al.* (2019), Gopal *et al.* (2018), Akbar *et al.* (2020a), Defranco e Laplante (2017), Moayedikia *et al.* (2020), Alsanoosy *et al.* (2020), Hussain *et al.* (2021), Nurrahman *et al.* (2021), Sridhar e Vadivelu (2022), Ludwig *et al.* (2022), Zhang *et al.* (2021), Garro-Abarca *et al.* (2021), Castro-Hernandez *et al.* (2022), Ali e Lai (2021), Khan e Akbar (2022)
Best Practice/Success factor - 34%	Richardson *et al.* (2012), Kamal *et al.* (2020), Hidayati *et al.* (2020), Akbar *et al.* (2020b), Khan *et al.* (2019), Imtiaz e Ikram (2017), Sangaiah *et al.* (2015b), Gulzar *et al.* (2018), Khan e Akbar (2020), Bhatti e Ahsan (2016), Chatzipetrou *et al.* (2011), Sievi-Korte *et al.* (2019), Gopal *et al.* (2018), Monasor *et al.* (2012), Akbar *et al.* (2020a), Lai *et al.* (2020)
Challenges/Barriers - 31%	Nguyen-Duc *et al.* (2015), Nidhra *et al.* (2013), Richardson *et al.* (2012), Ilyas e Khan (2017), Kuhrmann *et al.* (2016), Rafi *et al.* (2020b), Ilyas e Khan (2012), Shanyour e Qusef (2019), Goyal e Gupta (2020), Yaseen *et al.* (2016), Bhatti e Ahsan (2016), Dumitriu *et al.* (2011), Sievi-Korte *et al.* (2019), Vizcaíno *et al.* (2018), Šablis e Šmite (2016), Vizcaíno *et al.* (2019), Shameem *et al.* (2020), Khan *et al.* (2019), Akbar *et al.* (2020), Trinkenreich *et al.* (2022)
Risks and threats - 11%	(RICHARDSON *et al.*, 2012; LAMERSDORF *et al.*, 2012; KUHRMANN *et al.*, 2016; SUNDARARAJAN *et al.*, 2019; RASHID *et al.*, 2021; BASTIDAS *et al.*, 2021; BJÖRKDAHL; KRONBLAD, 2021)

The first column is the Analysis scenario and its percentage, and the second column is the studies and authors.

APPENDIX C – THE CLUSTERING ALGORITHM

Appendix C displays the Algorithm 3 - SBERT and *k*means Criteria Cluster.

Algorithm 3 SBERT and *k*means Criteria Cluster

```
#Loading the packages
import os
import pandas as pd

#Importing the SBERT pre-trained-model
from sentence_transformers import SentenceTransformer
embedder = SentenceTransformer('all-mpnet-base-v2')

#Importing the kmeans clusterign and the Word Cloud package
from sklearn.cluster import KMeans
import matplotlib.pyplot as plt
from wordcloud import WordCloud

# Loading the data
df = pd.read_excel('Criteria_description.xlsx')
df.head()

#Making the Sentence embedding operations
corpus = list(df['Definition'])
corpus
corpus_embeddings = embedder.encode(corpus)
corpus_embeddings

#Making the kmeans clustering operations
clustering_model = KMeans(n_clusters=25, random_state=0, n_init=300)
clustering_model.fit(corpus_embeddings)
cluster_assignment = clustering_model.labels_
cluster_assignment

#Print to spreadsheet
cluster_df = pd.DataFrame(corpus, columns = ['corpus'])
cluster_df['cluster'] = cluster_assignment
cluster_df['code'] = df['code']
cluster_df.head()
file_name = 'Grouped_topics_thesis_bert.xlsx'
cluster_df.to_excel(file_name)
print

#Clusters word clouds
def word_cloud(pred_df,label):
    wc = ' '.join([text for text in pred_df['corpus'][pred_df['cluster'] == label]])
    wordcloud = WordCloud(width=800, height=500,
    random_state=21, max_font_size=110).generate(wc)
    fig7 = plt.figure(figsize=(10, 7))
    plt.imshow(wordcloud, interpolation="bilinear")
    plt.axis('off')

#For each cluster replace 0 to (1, ..., 24)
word_cloud(cluster_df,0)
```

Source: author.

APPENDIX D – PRACTITIONERS DIRECT-INFLUENCE MATRIX

This Appendix D shows the First Practitioners' direct-influence matrix in Table D.1; Second Practitioners' direct-influence matrix in Table D.2; and Third Practitioners' direct-influence matrix in Table D.3. For more details see Subsection 4.2.1 - DEMATEL results

Table D.1 – First Practitioners' direct-influence matrix

Cluster	COMMUN	PROJRE	CONFMA	TEAMRE	PERSDI	TEORAT	TEAMSK	DATAEN	CHREMA	TASKRE	KNOWTR	SOFTCH	ORGANI	ARCHPR	STAKEH	SOCGEO	GENDSE	GREENSO	INTEGR	TRUST	PROCMA	AGITRA	INTERF	METRIC	SCIENT
COMMUN		4	4	4	3	4	4	2	3	4	4	3	4	2	4	2	3	3	2	4	4	4	2	2	3
PROJRE	0		1	1	1	1	1	3	4	2	0	4	0	4	2	0	0	2	4	0	1	1	4	1	0
CONFMA	1	4		4	4	4	4	1	3	4	4	2	1	2	2	1	1	1	1	3	4	4	1	1	1
TEAMRE	1	4	3		2	3	3	0	2	4	4	2	1	1	1	0	2	0	0	3	4	4	0	0	1
PERSDI	1	2	2	4		3	3	0	1	3	2	0	1	0	0	0	2	0	0	3	2	2	0	0	3
TEORAT	1	3	3	4	3		3	0	1	3	3	1	2	1	1	1	1	0	0	3	4	4	0	0	1
TEAMSK	1	2	3	4	1	3		1	2	4	3	1	1	3	1	0	0	2	2	3	3	3	2	1	2
DATAEN	1	1	0	0	0	0	0		1	0	0	1	0	2	0	0	0	1	2	0	0	0	1	1	0
CHREMA	3	4	3	1	1	1	1	2		1	1	4	1	2	3	0	0	1	2	1	3	3	2	1	1
TASKRE	2	3	4	4	4	4	4	1	3		3	1	0	2	0	0	1	0	0	3	4	4	0	0	3
KNOWTR	2	1	2	4	3	3	4	1	1	3		0	0	1	0	0	0	0	1	3	2	2	0	0	0
SOFTCH	3	2	4	1	1	1	0	4	4	3	1		0	3	3	0	0	1	3	1	4	3	3	2	0
ORGANI	4	0	4	4	3	2	2	1	2	2	2	0		1	2	4	3	2	2	4	4	4	0	2	2
ARCHPR	1	1	1	1	0	0	1	4	0	0	0	0	0		0	0	0	3	4	0	0	0	2	2	1
STAKEH	1	3	4	2	3	3	2	0	3	2	2	2	2	1		2	1	1	2	4	3	3	4	2	2
SOCGEO	4	1	3	3	3	3	3	0	2	2	2	0	2	0	1		3	1	0	3	3	3	0	0	2
GENDSE	3	0	1	1	1	1	1	0	0	1	0	0	2	0	1	2		0	0	1	1	0	0	0	0
GREENSO	1	1	2	0	2	3	2	2	1	1	2	1	3	3	2	0	0		3	0	2	0	0	0	1
INTEGR	0	2	1	0	0	0	0	4	0	1	0	1	0	4	0	0	0	3		0	0	0	0	0	0
TRUST	4	1	4	3	4	4	3	0	2	3	2	0	3	0	3	3	0	0	0		3	3	0	2	3
PROCMA	1	4	4	4	2	4	4	2	4	4	3	2	4	2	2	2	0	2	2	3		4	1	4	2
AGITRA	4	4	4	4	2	4	4	0	4	4	3	1	4	0	2	2	0	0	0	3	3		1	2	2
INTERF	0	1	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	3	2	0	0	0		0	0
METRIC	0	2	4	0	0	1	0	2	1	1	0	3	0	2	2	0	0	2	1	3	2	2	1		2
SCIENT	3	0	2	1	3	4	4	0	1	2	2	1	2	0	2	1	0	1	0	0	1	1	0	0	

For more details see Subsection 4.2.1

Source: author.

Table D.2 – Second Practitioners' direct-influence matrix

Cluster	COMMUN	PROJRE	CONFMA	TEAMRE	PERSDI	TEORAT	TEAMSK	DATAEN	CHREMA	TASKRE	KNOWTR	SOFTCH	ORGANI	ARCHPR	STAKEH	SOCGEO	GENDSE	GREENSO	INTEGR	TRUST	PROCMA	AGITRA	INTERF	METRIC	SCIENT
COMMUN		4	4	4	2	3	3	2	3	2	2	3	3	3	4	2	0	4	4	4	4	4	3	3	1
PROJRE	0		2	1	1	3	4	4	4	4	2	3	2	4	4	0	1	2	3	0	2	3	2	3	3
CONFMA	4	3		4	3	3	1	1	2	2	0	2	2	2	4	1	2	1	1	4	3	2	0	2	2
TEAMRE	4	3	4		2	3	4	2	3	4	3	2	2	1	2	2	3	1	1	4	3	3	2	3	1
PERSDI	2	1	3	2		2	1	0	0	2	2	1	2	1	2	2	3	1	1	3	1	1	0	1	2
TEORAT	4	3	2	2	2		3	3	3	4	4	3	2	2	3	1	2	2	2	4	3	2	0	3	2
TEAMSK	2	4	1	1	1	3		4	3	3	3	3	2	3	3	1	0	3	3	4	2	2	0	3	2
DATAEN	2	2	1	1	2	2	2		4	4	1	3	2	2	3	1	0	1	3	2	2	1	2	2	2
CHREMA	3	4	3	2	1	2	3	2		3	2	2	1	1	4	0	0	2	3	1	2	0	4	3	2
TASKRE	3	3	2	2	2	2	3	2	2		0	2	2	2	1	1	2	2	2	3	3	3	3	3	2
KNOWTR	4	0	0	0	2	1	2	2	0	2		0	1	1	1	0	0	0	0	3	2	2	2	2	2
SOFTCH	4	4	3	2	2	2	1	2	4	3	2		1	3	2	1	1	1	3	1	1	1	2	2	2
ORGANI	4	2	4	2	1	3	2	2	2	2	1	1		2	2	1	2	2	2	4	2	4	2	3	2
ARCHPR	3	3	1	0	0	2	4	2	3	1	1	3	1		0	0	0	2	1	2	3	2	2	3	2
STAKEH	4	2	2	1	2	1	1	1	3	1	0	3	3	1		1	1	1	1	3	2	1	2	2	1
SOCGEO	3	1	2	1	2	1	1	0	1	0	1	0	1	0	1		1	0	0	2	1	1	0	1	1
GENDSE	2	0	2	1	2	0	0	0	1	0	1	0	1	0	1	1		1	0	1	0	0	0	0	0
GREENSO	2	2	2	2	0	2	2	2	2	2	1	2	1	2	1	2	0		2	1	1	3	2	3	3
INTEGR	3	3	1	1	0	2	2	3	3	2	1	3	1	2	2	0	0	3		2	3	2	3	4	3
TRUST	4	1	4	4	4	3	3	2	2	2	3	2	2	2	3	0	3	1	2		2	1	3	3	2
PROCMA	4	2	2	2	1	2	2	2	2	2	1	2	2	2	2	1	2	2	2	2		2	2	4	3
AGITRA	2	2	1	1	1	1	1	2	1	1	1	1	1	1	1	0	1	2	1	1	2		2	1	2
INTERF	3	3	1	2	1	2	2	2	3	2	1	2	2	2	3	0	1	2	3	2	2	2		3	2
METRIC	3	3	2	3	2	3	3	2	3	3	2	3	2	2	3	1	1	3	3	2	3	3	2		1
SCIENT	3	0	3	1	3	4	4	0	1	2	2	1	2	0	2	1	0	2	0	0	1	2	0	0	

For more details see Subsection 4.2.1

Source: author.

Table D.3 – Third Practitioners' direct-influence matrix

Cluster	COMMUN	PROJRE	CONFMA	TEAMRE	PERSDI	TEORAT	TEAMSK	DATAEN	CHREMA	TASKRE	KNOWTR	SOFTCH	ORGANI	ARCHPR	STAKEH	SOCGEO	GENDSE	GREENSO	INTEGR	TRUST	PROCMA	AGITRA	INTERF	METRIC	SCIENT
COMMUN		4	3	4	2	4	1	4	4	3	4	3	4	2	2	3	4	2	1	4	3	2	3	1	2
PROJRE	1		4	2	4	4	4	3	4	4	2	4	2	3	3	1	1	1	1	2	4	4	3	2	4
CONFMA	4	1		4	2	2	1	4	4	2	0	3	1	2	4	3	3	1	1	4	4	1	1	1	3
TEAMRE	4	1	3		4	4	1	1	3	2	1	2	2	1	2	1	1	3	1	4	2	1	1	1	3
PERSDI	4	1	4	4		4	2	2	2	2	1	2	2	1	4	3	4	3	2	4	2	2	2	1	3
TEORAT	4	1	4	3	2		1	2	4	3	2	1	2	2	3	3	2	2	3	4	3	1	1	2	3
TEAMSK	3	1	1	1	0	1		4	2	3	1	2	2	4	2	1	1	3	4	3	2	3	4	3	2
DATAEN	2	4	3	2	1	1	0		4	1	1	2	2	3	3	1	1	2	3	4	2	1	2	3	3
CHREMA	3	4	4	3	1	2	0	2		3	1	4	2	2	4	2	0	2	2	4	4	1	1	2	3
TASKRE	2	0	2	3	3	3	1	4	3		0	2	1	2	2	2	2	2	4	4	3	1	3	2	2
KNOWTR	4	1	2	3	2	2	2	0	2	1		1	3	3	1	1	1	4	2	3	2	1	1	2	3
SOFTCH	2	2	3	3	1	2	1	1	3	2	2		1	3	2	1	0	3	4	3	2	1	3	1	2
ORGANI	4	2	3	3	1	4	2	2	3	2	4	2		2	4	4	4	3	2	4	4	3	1	3	4
ARCHPR	3	0	2	1	1	2	0	2	2	2	3	4	1		1	2	1	3	4	2	2	1	3	2	1
STAKEH	2	3	2	1	1	3	1	4	2	2	0	3	3	1		1	3	1	1	4	3	1	1	3	2
SOCGEO	3	1	4	4	2	3	1	2	1	2	2	1	2	1	2		3	1	1	4	2	1	1	1	1
GENDSE	4	0	3	3	2	4	4	2	1	1	1	1	4	0	4	4		1	1	4	2	1	1	3	4
GREENSO	1	1	2	2	1	3	1	2	1	1	4	3	0	3	1	1	0		3	3	1	1	3	2	2
INTEGR	1	2	1	1	1	2	2	2	3	1	1	2	1	3	1	1	0	2		2	2	1	2	2	2
TRUST	4	3	4	4	2	4	2	1	3	2	1	3	4	2	4	2	1	1	2		2	1	1	2	2
PROCMA	4	2	4	4	2	4	2	3	4	4	2	3	2	2	3	2	1	1	3	4		1	2	3	1
AGITRA	3	1	3	3	2	4	3	2	4	4	2	4	1	3	2	2	2	3	4	4	2		3	2	2
INTERF	2	3	1	1	1	1	1	2	2	3	1	1	1	2	3	1	1	2	3	2	1	1		3	2
METRIC	4	2	2	2	1	2	1	3	1	1	2	2	1	1	3	1	1	2	1	4	3	1	4		4
SCIENT	4	3	2	2	2	2	3	4	2	1	4	2	4	1	2	1	4	2	2	4	2	1	1	4	

For more details see Subsection 4.2.1

Source: author.

APPENDIX E – DEMATEL - INNER DEPENDENCE CONNECTIONS AND MATRIX $T^{'}$

Appendix E shows the Connections in the Inner dependence matrix $T^{'}$ - The dispatcher and receiver group in Table E.1, and Inner dependence matrix $T^{'}$ in Table E.2. See Subsection 4.2.1 - DEMATEL results for more details.

Table E.1 – Connections in the Inner dependence matrix $T^{'}$ - The dispatcher and receiver group

Groups	R_i	D_i	+	-	Identify
COMMUN	2.93	2.22	5.15	0.71	Cause
PROJRE	1.72	1.34	3.05	0.38	Cause
CONFMA	1.84	2.05	3.89	-0.22	Effect
CONFLIC	1.50	1.71	3.22	-0.21	Effect
PERSDI	0.85	0.80	1.65	0.05	Cause
TEORAT	1.75	1.98	3.73	-0.23	Effect
TEAMSK	1.87	1.12	2.99	0.75	Cause
DATAEN	0.18	1.07	1.25	-0.90	Effect
CHREMA	1.33	1.58	2.91	-0.26	Effect
TASKRE	1.44	1.61	3.05	-0.17	Effect
KNOWTR	0.61	0.89	1.50	-0.28	Effect
SOFTCH	1.29	1.08	2.37	0.21	Cause
ORGANI	2.25	0.54	2.78	1.71	Cause
ARCHPR	0.08	0.71	0.79	-0.63	Effect
STAKEH	1.10	1.46	2.57	-0.36	Effect
SOCGEO	0.54	0.16	0.71	0.38	Cause
GENDSE	0.08	0.17	0.25	-0.08	Effect
GREENSO	0.16	0.44	0.60	-0.28	Effect
INTEGR	-	0.71	0.71	-0.71	Effect
TRUST	1.82	2.26	4.07	-0.44	Effect
PROCMA	2.24	1.89	4.13	0.34	Cause
AGITRA	1.35	0.94	2.29	0.40	Cause
INTERF	-	0.36	0.36	-0.36	Effect
METRIC	1.14	0.88	2.02	0.25	Cause
SCIENT	1.15	1.21	2.36	-0.05	Effect

The dispatcher and receiver group of the matrix $T^{'}$

Table E.2 – Inner dependence matrix T'

Cluster	COMMUN	PROJRE	CONFMA	CONFLIC	PERSDI	TEORAT	TEAMSK	DATAEN	CHREMA	TASKRE	KNOWTR	SOFTCH	ORGANI	ARCHPR	STAKEH	SOCGEO	GENDSE	GREENSO	INTEGR	TRUST	PROCMA	AGITRA	INTERF	METRIC	SCIENT
COMMUN	0.10	0.13	0.15	0.14	0.10	0.14	0.11	0.11	0.14	0.13	0.11	0.11	0.12	0.10	0.13	0.08	0.09	0.11	0.10	0.16	0.14	0.12	0.10	0.10	0.10
PROJRE	0.08	-	0.10	0.08	-	0.10	0.09	0.10	0.12	0.11	-	0.10	-	0.10	0.10	-	-	-	0.09	0.08	0.10	0.09	0.09	0.08	0.09
CONFMA	0.13	0.09	0.08	0.12	0.10	0.12	0.08	0.09	0.11	0.11	0.09	0.09	-	0.08	0.11	-	-	-	-	0.13	0.12	0.09	-	-	0.09
CONFLIC	0.12	0.10	0.12	-	0.09	0.12	0.09	-	0.10	0.11	0.09	0.08	-	-	0.09	-	-	-	-	0.13	0.11	0.09	-	-	0.08
PERSDI	0.10	-	0.10	0.10	-	0.10	-	-	-	0.09	-	-	-	-	0.09	-	-	-	-	0.11	0.08	-	-	-	0.08
TEORAT	0.12	0.09	0.12	0.11	0.09	-	0.09	0.08	0.10	0.11	0.09	0.08	0.08	-	0.10	-	-	-	-	0.13	0.11	0.09	-	0.08	0.08
TEAMSK	0.10	0.09	0.09	0.09	-	0.10	-	0.10	0.10	0.11	0.08	0.08	-	0.10	0.09	-	-	0.09	0.09	0.12	0.10	0.09	0.09	0.09	0.08
DATAEN	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-
CHREMA	0.11	0.11	0.11	0.09	-	0.09	-	0.08	-	0.09	-	0.10	-	-	0.11	-	-	-	0.08	0.10	0.10	-	-	0.08	0.08
TASKRE	0.10	0.09	0.11	0.10	0.09	0.11	0.09	0.09	0.10	-	-	-	-	0.08	-	-	-	-	0.08	0.12	0.11	0.09	-	-	0.08
KNOWTR	0.10	-	-	0.09	-	0.08	0.08	-	-	-	-	-	-	-	-	-	-	0.08	-	0.10	0.08	-	-	-	-
SOFTCH	0.11	0.09	0.11	0.08	-	0.09	-	0.08	0.11	0.09	-	-	-	0.09	0.09	-	-	-	0.09	0.09	0.09	-	0.08	-	-
ORGANI	0.14	0.09	0.13	0.12	0.08	0.12	0.09	0.08	0.11	0.10	0.10	-	-	0.08	0.11	0.08	0.08	0.09	0.08	0.14	0.12	0.11	-	0.10	0.10
ARCHPR	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STAKEH	0.10	0.09	0.10	0.08	-	0.10	-	-	0.10	0.08	-	0.09	0.08	-	-	-	-	-	-	0.12	0.10	-	-	0.08	-
SOCGEO	0.10	-	0.09	0.09	-	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.08	-	-	-	-
GENDSE	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GREENSO	-	-	0.08	-	-	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INTEGR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TRUST	0.13	0.09	0.13	0.12	0.10	0.12	0.10	-	0.10	0.10	0.08	0.08	0.09	-	0.11	-	-	-	-	0.09	0.10	0.08	-	0.09	0.09
PROCMA	0.12	0.10	0.13	0.12	0.08	0.12	0.10	0.09	0.12	0.12	0.09	0.09	0.09	0.09	0.10	-	-	0.08	0.09	0.13	0.08	0.09	-	0.11	0.09
AGITRA	0.11	0.09	0.11	0.10	-	0.11	0.09	-	0.11	0.10	0.08	0.08	-	-	0.08	-	-	-	-	0.11	0.10	-	-	-	0.08
INTERF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
METRIC	0.10	0.08	0.10	0.08	-	0.09	-	0.08	0.08	0.08	-	0.08	-	-	0.09	-	-	-	-	0.11	0.09	-	-	-	0.08
SCIENT	0.11	-	0.09	-	0.08	0.11	0.10	0.08	-	0.08	0.08	-	0.08	-	0.08	-	-	-	-	0.10	0.08	-	-	0.08	-

For more details see Subsection 4.2.1 - DEMATEL results.

APPENDIX F – THE CLUSTERING ALGORITHM FOR STS

Appendix F presents the Algorithm 4 - STS cosine similarities between the clusters. See more details in Subsection 4.2.2 - Semantic Textual Similarities results.

Algorithm 4 STS cosine similarities between the clusters

```
# Data Structures
import numpy  as np
import pandas as pd

# Keyword extraction
from sklearn.feature_extraction.text import CountVectorizer
from sentence_transformers import SentenceTransformer
from sklearn.metrics.pairwise import cosine_similarity

# Loading the data
df = pd.read_excel('Clusters definitions_vf01.xlsx')
df.head()

# Importing the clustering algorithms - initialize our model and tokenizer
model_name = 'sentence-transformers/all-mpnet-base-v2'
from transformers import AutoTokenizer, AutoModel
import torch
tokenizer = AutoTokenizer.from_pretrained(model_name)
model = AutoModel.from_pretrained(model_name)

# Declaring the variables - tokenize the sentences
sentences = df['Cluster definition']
sentences
sentences_list = list(df['Cluster definition'])
sentences_list
tokens = {'input_ids': [], 'attention_mask': []}
for sentence in sentences_list:
    new_tokens = tokenizer.encode_plus(sentence, max_length=384,
                                   truncation=True, padding='max_length',return_tensors='pt',
                                   return_attention_mask=True)

    tokens['input_ids'].append(new_tokens['input_ids'][0])
    tokens['attention_mask'].append(new_tokens['attention_mask'][0])

tokens['input_ids']

# reformat list of tensors into single tensor
tokens['input_ids'] = torch.stack(tokens['input_ids'])
tokens['attention_mask'] = torch.stack(tokens['attention_mask'])

# Checking the variables
tokens['input_ids']
type(tokens['input_ids'])
tokens['input_ids'].shape

# Making the operations - Processing these tokens through our model
outputs = model(**tokens)
outputs.keys()

# The dense vector declarations of our text are contained within the outputs 'last_hidden_state' tensor
embeddings = outputs.last_hidden_state
embeddings
embeddings.shape

# Resize our attention_mask tensor
attention = tokens['attention_mask']
attention.shape
mask = attention.unsqueeze(-1).expand(embeddings.shape).float()
mask

# Multiply the two tensors to apply the attention masks
mask_embeddings = embeddings * mask
mask_embeddings
mask_embeddings.shape

# Then we sum the remained of the embeddings along axis 1
summed = torch.sum(mask_embeddings, 1)
summed.shape
summed

# Sum the number of values that must be given attention in each position of the tensor
counts = torch.clamp(mask.sum(1), min=1e-9)
counts.shape
counts

# Calculate the mean as the sum of the embedding activation's summed divided bythe number of values that should be given attention in each position counts
mean_pooled = summed / counts
mean_pooled.shape
mean_pooled

# The final operations - calculate the cosine similarity between the vectors
from sklearn.metrics.pairwise import cosine_similarity
mean_pooled = mean_pooled.detach().numpy()
data_25g = cosine_similarity(
[mean_pooled[0]],
mean_pooled[1 :]
)
data_25g # data_25g is the final similarities matrix.

#Print to spreadsheet
data_25gT = data_25g.T
data_25gT
dfdata_25gT = pd.DataFrame(data_25gT)
dfdata_25gT.to_excel("saida.xlsx", index=False)
```

Source: author.

APPENDIX G – THE DEFINITIONS OF EACH CRITERIA CLUSTER

This Appendix G present the Tables G.1, G.2, G.3, G.4, G.5, G.6, and G.7 with the definitions of each criteria group. These Tables present in sequence: cluster number, cluster name, cluster code, and cluster group definition. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters.

Table G.1 – Criteria cluster definitions 1-7

Cluster	Cluster name	Cluster code	Cluster group definition
g_5	Communication	COMMUN	Communication needs for adequate and proper ways of communication in general. In addition, the reduced communication frequency with the project team members became a problem due to the need for more informal or face-to-face contact. Each culture has its standards, styles, and moral principles, which can provoke communication-related issues when an individual with a different cultural background communicates with another. Temporal issues are related to the time difference between teams that work Delayed feedback and responses are problematic and restrict the possibility of synchronous interaction, cooperation, and confidential assessment. Loss of tacit knowledge due to the replacement of onshore with offshore staff. Reduced opportunities for synchronous communication were also a significant risk factor in GSD. Has the team met or talked personally? This event grows the relationship between people at different sites, increasing the efficient outsourcing relationships in organizational management. Due to the temporal distance, the use of synchronous communication becomes less. In general, limited face-to-face meetings can decrease the opportunity for informal interaction, leading to a lack of team awareness and cohesiveness. However, it can be very costly and time-taking to travel frequently to a remote location. Technical incompatibilities among distributed sites cause communication obstacles due to technological issues. Quality of communication tools and network speed between sites. The low quality of telecommunication bandwidth is a communication issue because the context, tone, and emotion could be disoriented. Information Management is critical due to sharing relevant information between team members. The delay in getting a response can expand the time needed to resolve the issues. Lack of interpersonal relationships originates due to geographical distance among globally distributed teams. Fear's impact can manifest itself in numerous ways, including the desire to prevent or limit communication with remote colleagues. In some instances, the objective can be to hinder the work of these remote colleagues directly. Socio-culture distance. Less overlapping working hours increase the possibility of using asynchrony communication, as the overlapping working hours is the only time synchrony communication is feasible. Since virtual teams rely on electronic communication, any internet downtime could isolate team members and halt workflow. Degree of communication concreteness is a manner element of communication conveyed by perceptible, precise, or specific terms. Working and workplace atmosphere. The effort to initiate contact. Use of English for communication.
g_8	Project requirements	PROJRE	A project's success or failure depends on the accuracy and effective management of requirements. Build quality comprises the risk variables, requirements analysis, design, and construction. Therefore, the project manager must be diligent in formulating and adopting appropriate quality processes, procedures, tools, templates, techniques, guidelines, and standards. Clear software requirements are compulsory for the quality product, and it changes till the completion of software development. That gradual changes create new challenges to deal with. Stakeholder Requirements, or user requirements, describe what users do with the system, such as the activities that users must be able to perform. Usually, we use narrative text, cases, scenarios, user stories, or event-response tables to document it. Failures to meet customer requirements and expectations are often related to misunderstanding and misconception. Involving end users during system development is paramount to ensuring project success. Customers usually show little involvement while discussing the requirements in detail during the development process, which may lead to a weak relationship between the developer and the customer. Requirements engineering meeting's needs: engaging a human facilitator and using rich communication media that supports data, videos, and audio integration; preparing agenda and following it; selecting relevant participants and informing them of times to participate in requirement meetings; timely exchanging supporting documents to give participants enough time to read the relevant material; enabling participants of requirements meetings to access the resources that contain information about the requirements. The high degree of requirements changes during the project may provoke significant delays, with a good chance of introducing errors and misunderstandings. Project methodology (approach, mentoring). Software quality control. Site characteristics, including analyst capability, programmer capability, language and tool experience, personnel continuity, and customer proximity, are variable factors in the task allocation decision. The main characteristics of the project are defined by the way the work groups are organized, the project manager's level of authority; the level of dedication of the project manager; the availability of resources; who manages the budget; level of dedication of project management administrative staff. Estimation and planning are related topics, but estimation is not planning, and planning is not estimation. Therefore, estimation should be treated as an unbiased, analytical process, and planning should be treated as a tiny, goal-seeking process.
g_{17}	Conflict management	CONFLIC	Project management performance questions: extent and frequency of plan changes; frequency of emergency meetings; agreement between effort invested and effort required; participant satisfaction; customer satisfaction; the number of post-delivery product changes. Skilled leadership that has the expertise to assess and analyze the impact of demanded changes and will make the right decision at the right time. There are project failure micro and macro-risk elements. Micro-risks can often be correctly determined, and alternative strategies put in place to mitigate their potential impact. Macro-risks on the other hand may not even be considered. Lack of ICT and technological cohesion. The firm's retained earnings mainly determine budget constraints, the net present value of its future investments, the quality of its management, and the liquidation value of its assets are other examples. Financial maturity is when a stand's anticipated future value growth will not increase the firm's net worth. Labor cost is the leading reason organizations go global, but the availability of human resources is more important than cost. Practitioners sometimes require support to have personal availability. The team experience evolves different project background issues arise due to the difference in working culture when developers from different countries need to work on a project that is not like the existing project background. Time pressure on people working on the project results in developers attempting to find shortcuts and adopting different approaches to complete software development to meet the given deadline. Lack of human resources, knowledge, and skills. Lack of suitable infrastructure for integration and the nonavailability of skilled human resources to solve integration issues in time hinder the integration process. Project instability manifests itself as changing team structures, responsibilities between sites, personnel changes, and roles of existing personnel. Human-related problems. Turnover (team/staff). Conflict management could be divided into affective and substantive conflict. Overloading of key personnel. Handling stress. We can better comprehend stress by exploring the circumstances or context (i.e., occupational or personal) surrounding the events. Flexibility. Handling soft issues. It is a behavioral characteristic comprised of misaligned interests, lack of report progress, and tasks' undesirability, making task distribution challenges. Lack of long-term planning. Management activities are not properly performed across the boundaries due to a lack of collaboration and communication. Lack of management commitment.

Sample of the Cluster groups definitions. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters and Table 4.26 - Criteria cluster list overview.

Source: author.

Table G.2 – Criteria cluster definitions 2-7

Cluster	Cluster name	Cluster code	Criteria cluster definition
g_{14}	Team relationship	TEAMRE	Teamwork is based on team member relationships that facilitate the development of mutual respect and trust. This leads to developing a cohesive motivated team that sees itself as a single unit regardless of its members' location. The primary ingredients that impact the software development productivity of globally distributed projects are project delivery rate, team size, and communication complexity. The relationships of overseas team members should be formalized to share and accommodate secret requirements and build trust. Cooperation and competition within the teams to fulfill the goals. Collaborative systems incorporate norms of equality and emphasize group accomplishments. Team spirit is the satisfaction and honesty that coexists between the team members and motivates them to do well or be the best. Cross-functional teams. Each team member, representing a different knowledge specialty, comes to a team with a different thought world so that each member understands the problem, critical elements, and steps in solving the problem differently from each other. Effective task partitioning between team members and sites can be modularized, phased, or integrated. Task allocation. Allocation of the core team. Allocation of a whole team. An increased amount of effort with modifications involving several developers across different sites. Increased needs for coordination when using experts from different sites. Difficulties evaluating work input due to distribution. Difficulties in synchronizing tasks. Insufficient matching of code to available resources. Mutual coordination among team members is the interactions and relationships among participants that have become increasingly crucial for coordinating work and improving performance. Mutual understanding. knowledge creation ability among the teams. This shared understanding is the set of norms, behaviors, and understanding team members have about the assumptions, tasks, work processes, and contexts necessary for effective and successful collaboration. The common work experience is the site's experience working together. Degree of collaborative task coupling. The number of involved sites. Task site dependency. Collaborative coupling, in broad terms, signifies the intensity of user-user interaction to accomplish a task. Learning to work together, master the domain, and understand mutual sub-domains may take years. This fact may result in underestimating the learning curve in multi-site software development. Distributed members must be aware of the rules and regulations they must observe during the project, and a shared vision for the project can align team members toward shared goals.
g_{19}	Personality dimensions	PERSDI	Emotional stability (i.e., calm, steady, self-confident, and secure), of the five major personality dimensions, conscientiousness and emotional stability, are the most valid predictors of performance outcomes across different occupations. Ability to solve their professional problems. The developer or a person proactively identifies and resolves potential problems with the proposed solution. Self-control is the personal aptitude and behavior to do work. Determination and effort. The effort reflects the effort exerted by the participant to complete the task, while exertion reflects the overall perception of strain caused by the task. The perceptual sensations represent three dimensions of perceived effort (sensory-discriminative, motivational-affective, and cognitive-evaluative dimensions). Accountability refers to the degree to which a person is liable and accountable for his/her acts and meets another person's expectations. It includes the extent to which a person seems reliable, consistent, self-confident, persistent, and responsible. Time management planning is a practice where people plan what they intend to accomplish and when on a given day. Creativity in problem-solving is capturing and getting inspired by external success stories. Individual analytical thinking is a personal soft skill where the developer is highly proficient in a software programming language to build codes with complex instructions. Accepting criticism gracefully. Instill the values of good human relations and the need to work cooperatively, accept criticism gracefully, be courteous and enthusiastic, and maintain friendly relationships. Somehow, personal religion and political factors and behavior also relate to inter-culture as every country has its law, rules, and regulations to follow by the citizens. Benevolence is the willingness to help, availability, sharing, faith in intentions, friendliness, openness, caring, and commitment. Extroverted behaviors, for example, tend to result in a higher frequency of communication through electronic messages and increased team performance. Enhanced sensitivity predicts both reactivities to adverse contexts and the propensity to benefit from supportive resources from favorable environments. Conscientiousness describes a person's ability to regulate impulse control to engage in goal-directed behaviors. It measures elements such as control, inhibition, and persistence of behavior. Age is the number of years a person has lived. Lifelong learning is the individual behavior to develop competencies for performing the various roles required in human life and figuring out the learning skills by keeping the learning curve unrestricted. The degree of personal information. The degree of personal affective intensity.
g_2	Team organization and attitude	TEORAT	Organizational commitments. Employees feel compelled to reciprocate when offered valuable resources via social exchange and reciprocity mechanisms. Support, as it constitutes a socioemotional resource, leads employees to experience affective commitment toward the organization. Furthermore, organizational support may contribute to an affective commitment by fulfilling basic socioemotional needs, such as affiliation, approval, and respect. Charismatic leadership. Experienced staff plays an essential role: a pre-start project briefing session; assigning inexperienced employees with experienced employees whenever possible; language training for long-term assignments if language is a crucial component; and briefings on payroll, pension, and tax aspects. Team rewards and recognitions. Team empowerment is defined as the collective belief in a group that it can be effective and its role in determining its effectiveness. Empowerment is the delegation of authority and decision-making responsibilities, strengthening the role of people and teams. Human resource practices should be selected that complement and support an organizational strategy. Capability to adopt team members. Contributing to discussions. Contribution to the team effort. A team's effort contribution is the participation in helping each other, mutual support of team members, suggestions, and contribution of teams on project outcomes. Team members' attitudes express the satisfaction or dissatisfaction towards an individual, working environment, or event and an individual's behavior. The impact of attitudes influences communication in optimistic and pessimistic ways because of the individual's religious belief, personal attitudes, mindset, and knowledge. Communicate clearly with team members when speaking and writing. Participation and support to solve issues. Team members' ability to assist in solving problems. The problem-solving ability or the inability to see the problem arises due to the uncooperative motivational attitude of higher-ranking management interacting with the team members at remote sites, resulting in a lack of team cohesiveness. Continuous organizational support. An organizational commitment can be triggered by a combination of three conditions: desire, compulsion, and obligation to work for the focal organization. Commitment provides a foundation for employees to engage in behaviors that support the organization. Employee facilitation includes individual initiatives, mentoring by a core team, and employee work-life balance. Also, work-life balance and the need for attractive packages for hiring. Persistent, conscientious responsiveness information of teams. Flexibility among teams. Adaptability is essential to organizational success due to environmental change. Brainstorming actions for organizations.

Sample of the Cluster groups definitions. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters and Table 4.26 - Criteria cluster list overview.

Source: author.

Table G.3 – Criteria cluster definitions 3-7

Cluster	Cluster name	Cluster code	Criteria cluster definition
g_9	Team skills	TEAMSK	Specialty ability of the teams. The gap in the teams' specialty ability would lead to some differences in performance. The practitioners with lower specialties might need more solid knowledge foundations (hard skills) and are comparatively weaker in thinking and learning abilities. Their self-confidence, motivation, and soft skills are insufficient. A total number of technical skills (one employee) comprise the following capabilities information technology, business domain, project management, and sourcing managing customers or suppliers. Team Skills Database. All global team members' technical capability and skill levels must be available to the Project Manager to facilitate effective global team operation. In addition, this information needs to be efficiently maintained, understood, and easily accessible. Skilled human resources are the type of skill or expertise of individuals available. Reasoning skills. The ability to reason with emotions, or emotional reasoning skills, is the ability to employ emotional knowledge to understand and analyze emotions. Specifically, it includes capabilities such as understanding the links between emotion-eliciting situations and emotional reactions and describing one's and others' emotional experiences. The usage of a different language among distributed team members. The English language is widely used as a professional language on national and international platforms. Team size refers to the number of people working together to achieve certain goals. Proficiency in a programming language and expertise and knowledge in the application domain. Experience in similar projects. Staff experience on similar projects, programming languages, and tool experiences. Communication skills in a second language. The prior experience measures the number of team programmers who have participated in at least one similar project. Therefore, the level of uncertainty is expected to decrease as the number of team members with relevant experience increases. We must base the selection of global team members on the project's technical requirements. Comprehension ability in a project context depends on information about the trustee's roles and type of experience with technology use. Therefore, the personal profile also provides more data about skills and knowledge, such as previous work experience and academic studies. This information will allow the trustor to perceive a trustee's capabilities rapidly and explicitly. Scrum expertise. Having previous experience in the roles, practices, processes, procedures, and artifacts in Scrum. Pilot knowledge between teams.
g_6	Data environment	DATAEN	Handling of data describes competence in handling data, also includes large data volumes and data security. Legislation and regulation with cloud provider. Data Aggregation is one of the critical challenges in the mining process; data searched, reported, and presented from a different source is vital to gain specific business objectives. Traceability of data is a key issue Working in a heterogeneous data environment. Data generated in real-time, i.e., online development systems, must check data assessment while sharing data in a continuous environment of DevOps during production. Proper tools are required to maintain continuous scalability and performance measures for better release. Data Harmonization. The increasing demand to integrate sizeable open data sets, ongoing updates, visualization, and analysis while addressing privacy and security concerns is a common problem. Storage of transition logs while considering data validity and security, storage of transition logs is a challenge in a DevOps environment. New visualization techniques and their assessments to implement or integrate new techniques Tools and technology: defect occurrence. Defect data contains knowledge about specific work conditions. A data feedback mechanism is required to prevent the reoccurrence of defects. Choose the right cloud service provider. Cloud computing is risky since there is no guarantee that the information is monitored or preserved by the service provider. In addition, the transition from local computing to cloud computing has created several security issues for the client and service provider. Efficient utilization of time and computing resources. Therefore, the scarcity of resources must be minimized to maintain adequate service, bypassing potential overloads. It is, therefore, essential to reduce the load on the server so that all users have equal performance. Misspelling in data entry. The development and operation teams working together in a DevOps environment may adopt best practices to resolve data entry issues avoiding misspellings in data entry. Missing information. The critical challenge in the DevOps environment is missing information and other invalid data due to integrating different sites in a software organization. Visualization of data it can be claimed that, without suitable visualization and understanding of large integrated data sets in a heterogeneous data environment, it is critical day by day to understand the purpose of data. Data provenance means the location of specific data and when and where that data was generated.
g_{23}	Change requirement management	CHREMA	Requirements change management is a rich communication activity in GSD and an efficient information sharing mechanism that facilitates the information management, integration, and coordination of Requirements change management activities across distributed sites. Monitoring and controlling the requirements change management activities at offshore sites. Contract management. Contract management involves building a good working relationship between client and contractor. It involves proactively anticipating future needs and reacting to situations or risks that may arise during the contract execution. The involvement of top and lower-level management is essential to successfully implement the Requirements change management process. Besides, the participation and commitment of the management could be helpful for requirement elicitation and change management. Internal project communication, intrainformation, and interinformation sharing across distributed sites. Vision and mission of demanded changes, knowing the scope and purpose of change management is important for the successful implementation of the requested changes. Collaboration, communication, and coordination: cross-boundary. Process awareness. It is much more important to hold workshops and seminars to motivate the team members to participate in process awareness. Degree of Business Process maturity. This change must be communicated if there are no stable requirements and requirement changes. This is not easily possible without maturity or good communication infrastructure between sites. In configuration management, the component version should easily track each component from start to final delivery. A different version of a product may have different sets and different versions of components, which need to be managed consistently and adequately for successful product integration. Potential differences in infrastructure across sites might lead to compatibility issues. Client and vendor organizational management commitment. Due to change frequently occurring in requirements during the system development process, organizational management must commit to and support change management activities. Therefore, upper and lower management involvement is essential to implement the RCM process successfully. Resistance management of change. The political environment influences the management effect of organizations on the requirements to change the management process because some organizations are hesitant to change the requirements. However, resistance management is essential in eliciting the desired requirements and effectively. Organization: strategies. Due to economic expansion, the sophistication of communication means, and cost pressure, it is crucial to comprehend the risks, challenges, opportunities, and good practices within this new software development scenario to construct business strategies.

Sample of the Cluster groups definitions. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters and Table 4.26 - Criteria cluster list overview.

Source: author.

Table G.4 – Criteria cluster definitions 4-7

Cluster	Cluster name	Cluster code	Criteria cluster definition
g_{10}	Task responsibilities	TASKRE	Criticality of the task. Criticality is the importance of getting the task done correctly in terms of its adverse effects should problems occur, and a critical task is one where a failure impacts the life of a human. Complexity is a function of the number of interconnected variables in the task. The most challenging tasks are those with a constraint on decomposition into simpler subtasks. The degree of task formality description is the role of methodology to perform or explain professional services. The degree of task information, a content element of communication in service exchanges, is conveyed through functional duty terms. The proportion of task terms to the number of words in a message defines the degree of task information. Task Size. First, when creating tasks for user stories at the beginning of each iteration, limit the size of the tasks to 4 hours, 8 hours, or no more than 16 hours in length. Thus, this will ensure that the team can work more efficiently in a fully integrated way. Task efficiency is the completion of assigned or agreed-upon responsibilities is the critical behavior of completing assigned tasks in a timely and efficient manner. Task effectiveness is significant because the uncertainty on product and technological novelty requires more design and development tasks to be completed on time, avoiding the increasing lead time uncertainty. Defined roles and responsibilities are essential to assign the proper responsibility and task to the right person and time. They should be clearly defined, articulated, and disseminated to all team members. Clear assignment of roles and responsibilities. Demonstrates initiative and responsibility for individual performance to get the job done under direct supervision. Coordination challenges level. Team coordination is defined as activities required to maintain consistency within a work product or to manage dependencies within the workflow. There are many different types of dependencies between task and task holders; these dependencies lead to a need for coordination among stakeholders working on a related set of tasks. When these coordination needs are not satisfied, they will have coordination challenges. Workload. As teams are distributed geographically and the communication among the distributed teams is less, tasks and responsibilities are not allocated properly. That may lead to a lack of shared understanding and confusion among the team members.
g_{21}	Knowledge transfer	KNOWTR	Knowledge interchange rate is a process of exchange of explicit or implicit knowledge between two agents, during which one agent purposefully receives and uses the knowledge provided by another. When the knowledge's codifiability is higher, the knowledge can be easily transferred to knowledge recipients. In some cases, employees need help finding updated knowledge transfer documents in their project repository, leading to delays in project delivery. Knowledge codifiability in an organizational project repository happens when complex knowledge is not codified in a high-level manner and is not straightforward to understand. The widespread use of the terms in the following list hint at the increased importance knowledge assets have in organizations: intellectual capital, knowledge capital, knowledge organizations, learning organizations, organizational learning, information age, knowledge era, information assets, intangible assets, intangible management, hidden value, and human capital. Knowledge-intensive business services, such as engineering, management consulting, and R&D, almost exclusively transfer knowledge and skills to client organizations. Absorptive capacity is the dynamic capacity that allows firms to create value and gain and sustain a competitive advantage by managing external knowledge. Understanding the process concerning knowledge transfer effectiveness on project outcome, also to ensure process improvement a common understanding of procedures should be established, process adherence should be ensured, and regular process audits should be conducted in all distributed sites. Learning of innovative technology is the participation, acceptance, and learning incentive of innovative technology in the global service climate. Tools and technology to facilitate knowledge transfer within the teams. These tools aim to increase the focal area's knowledge to a high level of knowledge that allows for solving problems and innovation. To facilitate the interpretation and integration of the knowledge transfer process, we must create norms providing a standard frame of reference and definitions of key technical terms. The client's knowledge loss becomes a problem of knowledge transfer when the company moves from an old vendor relationship to a new vendor relationship, as the client no longer holds all the information that the new vendor critically needs to involve in services with the client. While transferring knowledge from the client location to an offshore location, the knowledge transfer takes a long time and requires more iterations. It is difficult to measure how much cost it must invest for knowledge transfer.
g_{18}	Software changes	SOFTCH	Software changes are inevitable due to the dynamic nature of the software development project itself. One factor influencing the effectiveness of the change acceptance decision is the accuracy of the change effort estimation. Identifying change is the key activity, which indicates why, how, and when change is needed. Change acceptability refers to the quality of a software project dependent upon the satisfaction of the customers' needs and expectations. The impact analysis of a specific change request is important to estimate its effect on cost, time, and system quality. The poor analysis of the scope of demanded changes could cause the poor estimation of time, cost, and effort that could bring the project towards failure. Degree of the novelty of the product for involved persons. Novelty increases the difficulties in a project. When the requirement is changed or is new, team members might be unaware of new requirements or team members might not understand the requirements completely. The higher the novelty of project knowledge, the more difficult it is to transfer knowledge. Agile software development brings its own set of novel challenges that must be addressed to satisfy the customer through the early and continuous delivery of valuable software. The amount of working software produced determines progress in agile development. In addition, source code versioning, unit testing, continuous integration, and acceptance testing are technical factors that affect the software artifacts. Continuous Integration is a software practice where developers frequently integrate, at least daily. Refactoring is constantly improving the design of existing code without modifying the fundamental behavior. In Agile software project, the modularization approach segregates the code base into domain modules, identifies well-defined interfaces to these modules, and restricts the inter-module interactions through these interfaces. A code smell is a term commonly used to describe potential problems in software design. Agile software developers focus on polymorphic designs that meet the project's long-term goals. These features of agile methods support the development of green and sustainable software. The software development team must know the data's status before using it in the deployment phase to make data more consistent since continuous deployment leads all importance towards the development of the process, which causes errors and inconsistency in data.

Sample of the Cluster groups definitions. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters and Table 4.26 - Criteria cluster list overview.

Source: author.

Table G.5 – Criteria cluster definitions 5-7

Cluster	Cluster name	Cluster code	Criteria cluster definition
g_{20}	Organization	ORGANI	Organization: structure. The organizational structure that has proven effective in practice is characterized by a flatter structure, decentralized decision-making, greater collaboration and coordination, faster knowledge transfer between employees, knowledge networking, teamwork, proactive approach, horizontal communication, flexibility, and agility. Organization: resource. The resource-based view of the firm indicates that the activities in which an enterprise engages consist of a bundle of resources which include assets, processes, attributes, knowledge, information, and know-how that a firm possesses and can therefore use to formulate and implement competitive strategies. Organization: standard. Standard in an organization is a behavioral approach like style (textual, formal); the organizational and operational environment; organization condition; usage context; knowledge type; requirement purpose; organization customs; type of product; and development process. Organizational Policy is mainly expressed as a particular behavior of a person, which includes intentional actions to effect specific decisions to safeguard their interests. Organizational Practices are the behaviors and actions of employees. Hence, are the employees' daily work habits aligned with the core values of organizational culture? Practices are one of an organization's Five Ps (purpose, philosophy, priorities, practices, and projections). Organization: regulations. The regulation describes any attempt to influence a population's behavior, whether by law, force, nudging, or surreptitious manipulation. Organization: environment. The internal environment aspect can be observed using a functional approach consisting of production and operations, human resources, finance, management, and marketing information systems. The external environment is all circumstances outside the organization that has the potential to influence the organization. Stakeholder Attitude. In varying degrees, attitudes comprise three components, known to behavioral phycologists as the ABC Model of Attitudes Saul McLeod. The organizational size is defined as the number of employees at any given location. This would include the entire corporate organization if it is in one geographical location or a division of a decentralized corporation. The organizational culture encompasses the employees' values, beliefs, and behaviors. The error management culture refers to the organization's culture of bargaining with errors. A productive culture of error is a prerequisite for a successful digital transformation, especially during the transition phase. Culture of leadership. Employees desire good error management, forms of participation, and a culture of leadership that includes support and the establishment of common mindsets, stability, and reliability of corporate values.
g_{22}	Architectural practices	ARCHPR	Architectural design practices are about implementing well-defined interfaces to increase modularization and aid loose coupling. Strive for high modularity and separation of concerns. Locate dependencies within architecture. Software architecture's development, maintenance, and evolution appear to be crucial, especially concerning the definition of interfaces. Lack of alignment between architectural decisions to organization structure and not reflecting architectural changes to an organization; challenges brought by misalignment between organization and architecture; challenges brought by personnel changes; difficulties ensuring compliance of modular design throughout the lifecycle and changes in an organization. Align architecture with organization arrangement, include business goals in design, base architectural decisions on available resources, and establish quality management practices. Conformance to share practices is the ignorance of or incorrect use of principles, rules, and guidelines for architectural design and knowledge management. Lack of stability in architecture leads to difficulties in applying design rules and dividing tasks. Inconsistent versioning. Insufficient interface specifications. Architecture-based task allocation identifies where the domain expertise lies and allocates tasks accordingly. Retain tightly coupled work items at one site. Acquire and arrange resources based on architecture. Establishing practices enhancing communication and knowledge distribution. Architects should handle communication with different stakeholders, considering stakeholders' backgrounds. Communicate architectural artifacts and practices clearly to all sites. Maintain a single repository for architectural artifacts accessible to all. The standardized architectural practices ensure that teams develop code based on standard design agreements. Lack of continuous and active management of the architectures, including change control with a representation of all parties involved, is likely to lead to major problems, which appear to be detected only during the integration stage of the project. Compliance to processes. Impractical condensing of knowledge due to high dependency on one lead architect. Assign responsibilities for prioritization, managing architectural work, and sharing knowledge to teams. Break work items into easily manageable pieces (consider one subsystem, can be handled by one person). Define clear responsibilities for the architecture team to handle changes spanning several components and/or sites. Insufficient knowledge management practices between projects and across the organization. Problems recognizing and caused by conflicting assumptions on software. Incorrect assumptions made during design. Unclear ownership of architectural elements. Architecting modeling techniques use (call) graphs/matrices to depict and detect coupling. Use visualization of decisions/metrics.
g_3	Stakeholders	STAKEH	The stakeholder relationship is associated with customer feedback to improve development. Stakeholder involvement is essential for successful project delivery and is often considered a boundary activity or one that can be outsourced to business functions as usual. Nonetheless, project managers depend on people to respond to the outputs and benefits they deliver, and people will only respond if they are engaged. Understanding over the client's business process environment. The knowledge of the client's language and culture. Gathering the information and experience among teams. Stakeholder: Client. The person paying the bill, or the initial paying customer, can be seen to be the project client. Stakeholder: problem domain. Pushing knowledge beyond the constraints of the previous domain into new fields means that the boundaries of a theory receive more testing and support. Furthermore, these advances mean a greater understanding of when a theory works and why. Thus, the problem and solution domains are considered more mature. Communicate civility with the team. In a team context, civility is acting with empathy, compassion, and kindness in every interaction and treating everyone connected online with dignity and respect. Communicate civility with stakeholders. In a stakeholder's context, civility is acting with empathy, compassion, and kindness in every interaction and treating everyone connected online with dignity and respect. Stakeholder Performance Domain. This domain addresses activities (identifying, analyzing, prioritizing, engaging, and monitoring) and functions associated with stakeholders. Communicate clearly with stakeholders. Communicate clearly with stakeholders when speaking and writing to understand the direction of the stakeholders. Globally compete to market. Global competition becomes a form of international competition in which the position of an enterprise in one country affects its competitive position in other countries. As a result, companies compete for international leadership.
g_0	Social and Geographic	SOCGEO	Social facilities. Inequality manifests in the unequal provision of social amenities within the districts of the local government. The social amenities are educational, health, and market facilities, like drinking water, sanitation, electricity, housing qualities, and drainage arrangement. It is connected to the geographic dimension. Social interaction is how individuals act and react concerning one another. Frequency of social events. Social events include but are not limited to telling people what to do, spending time with sharp and witty people, giving speeches, attending parties, laughing without reservation, voicing strong personal values and opinions in a group, telling jokes, criticizing someone, and asking for help or advice. Communality refers to the personal characteristics that the trustor has in common with the trustee, like a similar goal they wish to achieve, shared language use, common identity characteristics, or shared values. It is a personal technical dimension. Collaborative work friendly is the ability to function on multidisciplinary teams. In today's multicultural world, this outcome also implies an ability to collaborate with people from different cultures, abilities, and backgrounds. Internalized norms are integrity, discretion, honesty, fairness, and loyalty. This criterion refers to the intrinsic moral norms a trustee uses to guard his/her actions. The language Analysis regarding how a trustee uses the chat and walls could infer some people's values. Communication protocols and customs. A communication Protocol is a system of rules that allows two or more entities in a communications system to transmit information via any variation of a physical quantity. Communication protocols are formal descriptions of formats and rules for producing digital messages for electronic data exchange. Climatic condition. Weather generally refers to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over more extended periods. Climate is the average weather conditions for a particular geographical location over notable years. Geological condition. Ecological-geological conditions are considered a geographical environment created by a set of contemporary morphologically expressed geological factors that influence specific features of the functioning of the biota, including human beings, within the framework of the ecological-geological system.

Sample of the Cluster groups definitions. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters and Table 4.26 - Criteria cluster list overview.

Source: author.

Table G.6 – Criteria cluster definitions 6-7

Cluster	Cluster name	Cluster code	Criteria cluster definition
g_{13}	Gender segregation (Women)	GENDSE	Gender segregation at work is widespread; within software engineering, the gender composition of contract workers differs significantly by occupational subspecialty. For example, women are far more prevalent in software quality assurance than in other software subspecialties. Work-Life Balance Issues (Women). After the COVID-19 pandemic and suddenly working from home, women reported being pressured to work overtime, with no working hours limits, and having to attend meetings in different time zones or learn new knowledge. Thus, they would be excluded from decisions made in meetings and perceived by others as lacking in teamwork. Benevolent Sexism (Women) represents the subjectively positive feelings towards gender that often bring some sexist antipathy. Lack of Recognition (women). Feeling valued or appreciated is part of Maslow's hierarchy of human needs. The woman mentioned not being recognized for her work and that the women's results are usually evaluated as OK, never as excellent, even when they perform exceptional work. Lack of Peer Parity (Women). Being surrounded by similar individuals to which to compare oneself or identify with at least one other peer in the team is known as peer parity. Impostor phenomenon (Women) or Syndrome describes an experience of individuals who, despite their objective successes, feel persistent self-doubt and are exposed as fraud or impostor. The women mentioned it as a challenge and reason to leave situations in which women personalize failures and feel ashamed and inferior more than men. They tend to escape the job but always mask as personal reasons. Pay inequality between genders (Women) and inferior career growth opportunities. Men raise only their counterparts to the top layer. Lack of transparency about the laddering criteria. Prove-it Again (Women) is a bias effect that occurs when a group member who does not align with the stereotypes is measured by a stricter criterion than those who align with them. So, for example, women always need to show competence: put extra effort to be heard when there is competition between men and have no room to slip[up]. Maternal Wall (Women) expresses the experience of mothers whose coworkers perceive and judge them as having made one of two choices: either they continue to work and neglect their family, making the motherless likable, or the mother prioritizes family over work, making them less reliable in the workplace.
g_4	Green software development	GREENS	A Green or Sustainable Product Life Management strategy could be defined as follows. First, Company's Mission by supplying products that satisfy customer needs considering all the lifecycle impacts. Then Vision, when the company coordinates the generation, change, and storage of all the relative product metadata with metrics that will assess the sustainability of all the product lifecycle phases. Finally, the Objective is to share data, information, and knowledge of all the product lifecycle stages, to encourage collaboration with all stakeholders, and enable sustainability through Green Products and Processes. Reuse ability. The application of reusable requirements catalogs to the development of software products implies changes in the basic Requirements Engineering process model (elicitation, analysis and negotiation, documentation or specification, and validation). The differences between the reuse-based and general process models are mild but may still lead to some process overload. Limited support for reusability. Usability consists of how users' features affect the use of an interactive system in the work environment. So, software reusability is an attribute that refers to the expected reuse potential of a software component. Minimal reengineering. Reengineering systems on a microservices-based architecture can be seen as implementing a service-oriented architecture (SOA). However, deploying SOA in a company is demanding, as it may implicate updating mission-critical systems with high technical debt and maintenance costs. Thus, a process is required that supplies a fine set of stages and techniques that minimize risks and simultaneously ensure the quality of the systems during the migration process. Software reuse not only improves productivity but also positively impacts the quality and maintainability of software products. E-waste minimization. The electronics industry is the largest and most innovative industry in the world. However, after a time of use, it becomes a complex residue. It contains many hazardous heavy metals, acids, toxic chemicals, and non-degradable plastics. Interfacing with different layers of the development framework. If an application must maintain persistent data, a mechanism for allowing it is required. CRUD pattern could be used to maintain a database and manage the life cycle of creating, updating, deleting, and reading data. In addition, it is essential for modeling related entity classes. Use of software tools. Evaluating and selecting software packages that meet an organization's requirements is a complex software engineering process.
g_{11}	Component integration	INTEGR	Data integration this request for integration implies that all the development artifacts in software processing are constantly accessible, even if they reside across different development tools. A clear integration plan is necessary to ensure efficiency and without extra complexity when finally putting the system together. Thus, integration asks for a centrally controlled approach. Similar programming languages. In GSD, many software components are not properly integrated due to the heterogeneity of software programming languages, operating systems, and communication tools. In addition, a common infrastructure is not shared between sites, making integrating components developed on these sites complex. In incremental integration, pieces of software are integrated into increments to avoid extensive integration. Thus, if we set an initial stage for the integration of components, while some components may still be in the development stage, it may be more valuable and save precious time during later stages of integration. Component or Unit Testing prior to integration. Suppose the distributed teams submit their developed components to the central team without proper component or unit tests. In that case, the integration phase will reveal many problems delaying the whole development process and fixing one problem may introduce another problem. The specific integration timing in the integration phase, or the synchronizing of the various parts, is one of the most challenging phases of software projects in the GSD environment. Software testing methods. Components are delivered untested due to pressure caused by time constraints on the development teams. They should be properly unit tested before integrating them into the final system as they are developed for some specific use cases. In almost 80% of the projects, the integrator finds defects during integration due to improper unit testing. Proper documentation. The root cause of most integration problems is inadequate documentation. Many project documentation is hard for the client organization because most of the knowledge concentrates and remains hidden in the vendor organization. In some cases, even if the documentation exists, it is obsolete and plays no role other than introducing new people to the coarse grain. Compatibility of data. Lack of compatibility. The GSD teams may use diverse platforms and tools to develop software components or subsystems. These components/subsystems raise compatibility problems during integration.
g_{15}	Trust	TRUST	Trust building. Personal or impersonal, including cognitive trust, refer to beliefs about others' competence and reliability. This can lead individuals to engage in less self-protective actions and be more likely to take risks. Trust among team members is the confidence of development team members. The ability to motivate others and create trust happens when a person can motivate and inspires; builds potential in others; creates an environment that fosters learning, collaboration, and fluid teamwork, and attracts high performers. Trust: confidence in the company and leadership and other stakeholders. The mere act of mingling with employees promotes the concept of the leader as just another colleague. During that interaction, if employees feel confident expressing a personal concern or need, presumably due to preexisting trust, the leader should act on that to further reinforce trust and demonstrate care and respect. If the leader acts reasonably, trust and confidence in the leader will increase. Trust: cross-boundary. Trust building is a critical factor for developing cross-boundary information sharing and, in a much broader sense, is a crucial element of the social capital needed for any successful cooperation or collaboration within and across social networks. Mediating role knowledge transfer. Strong ties are effective in providing valuable knowledge. Such relationships are helpful because they tend to be trusting. The benevolence and competence-based trust mediate the link between strong ties and the receipt of helpful knowledge. Eminence Education is reserved for individuals with fully developed talents who are incredibly talented in a domain relative to other highly accomplished producers and performers. This relative superiority is recognized by senior members of the domain. It is usually related to sustained contributions or contributions that have had or will have a lasting and memorable impact on the domain. Diplomacy comes from the intercultural competence of specialists, i.e., the formation of practical skills and abilities that ensure the ethnocultural perception of the individual development and his/her ability to correctly interpret specific manifestations of verbal and nonverbal behavior in different ethnic cultures.

Sample of the Cluster groups definitions. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters and Table 4.26 - Criteria cluster list overview.

Source: author.

Table G.7 – Criteria cluster definitions 7-7

Cluster	Cluster name	Cluster code	Criteria cluster definition
g_{16}	Process Management	PROCMA	Process Management. A process that directly addresses the specific requirements of the global team environment needs to be developed and implemented. Adequate training on the process operation should be provided to all team members. Shared ownership of the process should be fostered between team members across locations. Traditional standards and procedures. The practitioner should adopt formal standards and procedures for success. The team members should use formal processes, frameworks, and best practices. The standards and procedures guide the practitioners about what to do and how to do it. Process ownership. Process ownership is defined as placing ownership with those closest to the process who experience bottlenecks and inefficiencies. Process owners are responsible for getting the work done by workers, designing it, and ensuring the execution and high performance of the process in different organizational units. Software Process improvement - Consultancy. The consultancy in software process improvement is the capability of the consultants, based on their experience, to help small and medium Web companies adopt formal software process improvement standards while remaining aligned with the Web company's vision. Process improvement evaluation. Most process improvement evaluation strategies are generic. Different organizations apply those methods for measuring success indicators based on organizational needs and contexts, indicating a shortcoming in the methods used and supporting the demand for a comprehensive measurement framework. Process improvement standards and procedures. Process improvement standards and procedures: a set of policies and standard procedures describing how the firm's processes will be conducted and maintained consistently. Uniform processes. Lack of uniform process between different development sites. Best practices are to organize process-based training for new employees; ensure that management-level workshops synchronize global processes; follow standard processes and tools; follow a single process with all teams; follow documentation standards; adopt process evaluation standards and establish process training programs in the organization. Process phase (lifecycle). The process phase (lifecycle) comprises the development, distribution, acquisition, deployment, use, maintenance, deactivation, and disposal phases.
g_{1}	Agile and training	AGITRA	Team training and monitoring. Types of training: Induction Program, Training on Application Functionality, On the job Training, Trainee ramp-up. The education and support to distributed team members are essential in GSD. Advance and Uniform Development Environment and Training. For the Advance and Uniform Development Environment, all the development teams in GSD must use the same development environment. Even to use the latest technology and tools, the developers need to be trained appropriately to acquire the required skill and knowledge to ease the integration process in the long run. Agile training. Adopting Agile-driven team training methodologies is an efficient way of excelling in agile software project management with significant advantages in production costs, time-to-market, complexity, and quality improvement over traditional human resource management methodologies. It is a human resource dimension. Scrum hours. Scrum is the most widely applied Agile methodology and is a process framework for delivering products and services of the highest possible quality and handling complex problems or situations. Iterative and incremental approaches are used to develop products using cross-functional teams. Number os sprints. The number of sprints is short work cycles for incremental development. Scaling tools and standards. Beyond regular global projects, agile scaling involves many challenges, including coordination among multiple agile teams and the need for an initial architecture and requirement analysis. Several frameworks for scaling agile software development have been suggested, such as the Scaled Agile Framework (SAFe), Disciplined Agile Delivery, Large-Scale Scrum, Nexus, and Scrum@Scale. Training of DevOps activities. Training in DevOps activities has a positive impact while implementing DevOps. Formal training sessions are required to understand the concept and DevOps environment properly. The organization must support its teams with training sessions to help their organization successfully work on DevOps activities.
g_{24}	Component interface	INTERF	Proper component interfaces. Lack of proper component interfaces is the interface through which a component requests services or provides services. Inconsistencies between components/modules create problems during the integration stage. Component dependency. Software component dependencies in a product architecture give rise to communication and coordination needs. The architectural mechanisms other than module or software component dependencies also create coordination requirements. The software component dependencies must be addressed before allocating to temporally distant sites can be taken. Interface Compatibility. In software development, different components in a product interact and integrate through well-defined interfaces. Through interfaces, the component avails and provides services. Therefore, the software developer should develop in-house components or select COTS components that are loosely coupled and have well-defined software interfaces to fit into the final product easily. Components evaluation. Almost all types and sizes of software are composed of more than one software component or module developed in-house or outsourced. Similarly, in components evaluation, the components may be purchased from the market as a commercial off-the-shelf (COTS) component or from the large pole of the open-source community as an off-the-shelf (OTS) component. Product size. The product size to be developed comprise program code, an integral component of the software; architectural design size: components, their functions, and their interactions (interfaces); and specification size like the Unified Modeling Language. Identifying dependencies on architectural design decisions. Identifying dependencies on architectural design decisions, insufficient decoupling, or cross-component features are challenges brought about by software complexity and difficulties defining logical entities and finding interface boundaries in architecture. Product selection and customization (off the shelf). Due to time and budget constraints, selecting a proper component and customization from a large pool of components is challenging. Furthermore, in the case of open-source software (OSS), there are problems in the selection, maintenance, integration, and licensing of OTS (off-the-shelf) components.
g_{12}	Quality metrics	METRIC	Quality of test. Test quality underlies the risk variables, adaptation, regression, and performance tests. A regression test ensures that software changes do not break functionality. Performance tests are performed to ensure that software changes do not affect application performance. A retrofit test is about incorporating changes already made to production code in parallel by other project teams. Metrics to assess risk-based testing. Metrics to assess risk-based testing is to assess how many risks we mitigated through risk test cases. In addition, it allows checking how many risks we mitigated per requirement. Finally, identifying prioritized risks allows us to confirm prioritized risks with the highest level of requirements. Metrics to assess risk-based testing activities (time). Metrics to assess risk-based testing time identification allows knowing the average time taken to analyze a requirement with a certain number of lines. Assessing risk identification activity allows for setting useful or meaningful risks to develop test cases. Automated metrics allow for to definition of code complexity metrics. Semi-automated metrics allow us to measure functional complexity, for example. Finally, manual metrics allow the frequency of use and the importance for the user. Code coverage concepts and tools. Code coverage measures the degree to which a test suite exercises a software system. Software testing is often used to determine and sometimes improve software quality. However, it is also very labor and resource-intensive process that often accounts for more than 50% of the total cost of software development.
g_{7}	Scientific attitude	SCIENT	The scientific attitude is a willingness to change one's theory in the light of new empirical evidence critically. This attitude is a community ethos, not a psychological trait of individual scientists. Computer anxiety (personality dimensions). Independence of thought and action is the person who applies critical thinking to develop fairness, insight into the personal and public level, humble intellect and postponing the crisis, spiritual courage, integrity, perseverance, self-confidence, and research interest. In terms of anxiety, individual computer anxiety is the interactions with computers, negative global attitudes, and negative cognitions or self-critical internal dialogue. Lack of conviction issues. The personal conviction issue is related to someone relying on verified evidence rather than personal observation, which can be biased, error-prone, and spotty. The rigorous, demanding experimental design constraints are needed (or even morally obligated) when the findings might contradict strongly held prior beliefs and practices.

Sample of the Cluster groups definitions. For more details, see section 4.2 - 3D hierarchical structure of the Criteria clusters and Table 4.26 - Criteria cluster list overview.

Source: author.

APPENDIX H – ALGORITHM FOR THE 3D BUBBLE CHART

This Appendix H displays the Algorithm 5 - Algorithm for the 3D bubble chart. For more details, see Subsection 4.2.3 - The proposed method.

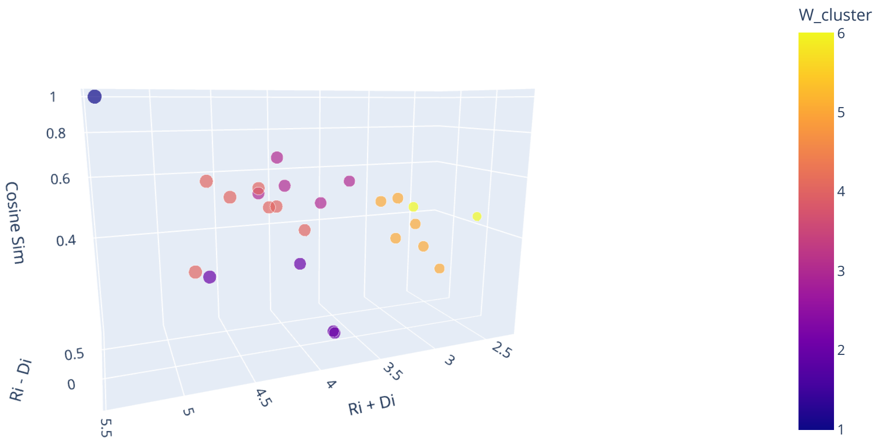
Algorithm 5 Algorithm for the 3D bubble chart

```
import plotly.express as px
import numpy as np
import pandas as pd
```

```
df = pd.read_excel('file_3D.xlsx')
df.head()
```

	Cluster	Description	Ri + Di	Ri - Di	Cosine Sim	W_cluster
0	COMMUN	Communication	5.42	0.43	1.000000	1
1	INTERF	Component interface	4.69	0.16	0.333691	2
2	SCIENT	Scientific attitude	3.91	0.25	0.332624	2
3	METRIC	Quality metrics	3.69	0.04	0.213171	2
4	GREENSO	Green software development	3.69	0.01	0.212376	2

```
fig = px.scatter_3d(df, x='Ri - Di', y='Ri + Di', z='Cosine Sim', size='Ri + Di', color='W_cluster',
                    hover_data=['Description'])
fig.update_layout(scene_zaxis_type="log")
fig.show()
```



Source: author.