ANALYSIS OF ORGANISATIONAL PERFORMANCE INITIATIVES CONDUCTED THROUGH THE CAPABILITY MATURITY MODEL INTEGRATION (CMMI V2.0) APPRAISAL METHOD

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Abstract
The Capability Maturity Model Integration (CMMI) has emerged as a critical framework for assessing and enhancing the maturity and capability of organisations in various industries. This model provides a structured approach for organisations to improve their processes, which ultimately leads to enhanced product quality, increased efficiency, and greater customer satisfaction. This introduction sets the stage for a comprehensive exploration of the value and evolution of CMMI in the context of contemporary organizational practices, followed by an analysis of the value brought by the current version 2.0 to modern organizations. For this analysis, 13 studies have been selected and systematized using a detailed systematic literature review protocol. As a result, this analysis helps gain insights into the value brought by the framework models, the challenges that organisations face when implementing the current version, and a mapping of the industries where the framework models have been in use since the current version released in 2018. Additionally, a series of literature gaps are brought forward, which can constitute the basis for future research. From a technical perspective, this paper provides insights into the techniques for performing a Maturity Model analysis and how to gain insights by conducting a systematic literature review. From a. content

point of view, the theme of value offering for organisations looking to implement/update Version 2.0 in their practices by analysing success stories and providing ideas on how to integrate this framework in their existing processes, as well as the challenges which might be encountered along the way. Based on the available information from Information Systems Audit and Control Association governing body, it is expected that the study of Maturity Models will draw more attention in the context of preparing the release of Capability Maturity Model Integration Version 3.0.

Keywords

capability maturity model integration; industry assessment maturity models analysis; organizational assessment; organizational performance; qualitative analysis; systematic literature review.

Research background

The Capability Maturity Model Integration (CMMI) has emerged as a critical framework for assessing and enhancing the maturity and capability of organizations in various industries. This model provides a structured approach for organizations to improve their processes, leading to enhanced product quality, increased efficiency, and greater customer satisfaction. This introduction sets the stage for a comprehensive exploration of the value and evolution of CMMI in contemporary organizational practices, followed by an analysis of the value brought by the current version, CMMI v2.0, to modern organizations. To understand the significance of CMMI, it is essential to delve into its historical development. CMMI traces its roots back to the late 1980s when the Software Engineering Institute (SEI) at Carnegie Mellon University initiated the development of maturity models to address the challenges faced by the software industry. The initial model, known as the Capability Maturity Model (CMM), aimed to establish a structured framework for assessing an organization's software development processes. This ground-breaking work later led to the development of CMMI.

In 2002, CMMI Version 1.1 was introduced, integrating multiple disciplines, including systems engineering, software engineering, and hardware engineering. The CMMI V1.1 presented a unified framework for organizations to improve their processes across various domains. In subsequent versions, such as CMMI V1.2 or V1.3, the model was refined and expanded to cater to a broader range of industries and practices. At its core, the fundamental value proposition of CMMI lies in its ability to drive organizational excellence through process improvement. It provides a roadmap for organizations to assess their current processes, identify areas for enhancement, and systematically progress toward higher levels of maturity and capability. This journey toward process maturity brings several tangible benefits, which can be classified into five main categories: competitive advantage, customer satisfaction, enhanced product quality, increased efficiency, and risk mitigation. These five categories are described in detail in Table 1.

While CMMI originated in the software and systems engineering domains, its applicability has expanded across various industries. As such, besides the engineering sector, organizations in sectors as diverse as academia (White, Longenecker, Leidig, & Yarbrough, 2003), aerospace (Miyashiro, Ferreirao, Spínola, Pessoa, & Gonçalves,

2016), automotive (Sassenburg & Kitson, 2006), banking (Chang &, Chen & Hung & Chen & Chen, 2013), cybersecurity (Butkovic, & Caralli, 2013), defense (Monarch et al., 2008), government (Beynon, 2007), healthcare (Pak & Song, 2016), manufacturing (Shah & Siadat & Vernadat, 2009), and telecommunications (Latif & Din & Ismail, 2010) have embraced earlier CMMI versions to enhance their processes and achieve better outcomes. These examples showcase the versatility of CMMI in improving processes, quality, and performance through various industries.

Table 1. CMMI benefits categories (Source: Authors' own contribution)

Benefit category	Benefit description
Competitive Advantage	Achieving higher CMMI maturity levels can be a competitive differentiator for modern organizations. This attribute can showcase organizational commitment to excellence in process management, which in turn can attract clients and partners who value reliability and quality in an organization's portfolio offering (Chrissis, Konrad, & Shrum, 2009).
Customer Satisfaction	By consistently delivering high-quality products and services, organizations can enhance customer satisfaction and foster long-term relationships (Dybå & Dingsøyr, 2008).
Enhanced product quality	Organizations that implement CMMI practices consistently report improved product quality. By establishing robust processes and focusing on preventive measures, defects can be minimized, leading to higher customer satisfaction and diminishing rework (Dybå & Dingsøyr, 2008).
Increased Efficiency	CMMI promotes efficiency by streamlining processes and reducing waste. By following a data-driven approach, organizations find themselves in a state that allows them to optimize resource allocation and reduce cycle times (Herbsleb & Goldenson, 1996).
Risk Mitigation	CMMI encourages proactive risk management. Organizations can avoid costly setbacks later in the project lifecycle by identifying and addressing potential risks early in the development lifecycle (Ahern, Clouse, & Turner, 2008).

As shown, CMMI has not remained static since its inception. It has continuously evolved to meet the changing needs of organizations and industries. The ongoing development of CMMI reflects its adaptability and relevance in the face of evolving business environments. One significant milestone was the release of CMMI Version 2.0 (CMMI V2.0) in 2018. This version was designed to be more flexible, scalable, and customizable, allowing organizations to tailor their process improvement efforts to their specific goals and contexts. Additionally, CMMI V2.0 enforced the concept of performance improvement, emphasizing the importance of achieving measurable outcomes. This shift towards performance-driven improvement aligns with the broader trend in the business world, where modern organizations are increasingly focused on results and impact, thus delivering value to their customers and users. Integrating digital technologies, automation, and artificial intelligence has introduced new complexities and opportunities for developing the CMMI framework, which

organisations should investigate leveraging. As a result, this action would ensure that their digital initiatives are well-managed, secure, and aligned with business objectives. After an extensive review of the existing literature, it has become evident that there is a notable gap in academic research. Specifically, there is a lack of scholarly studies that analyze organizational performance initiatives conducted through the Capability Maturity Model Integration (CMMI) appraisal model. This gap implies that there is a significant opportunity for further research and investigation in this area. By addressing this gap, this paper can contribute to a deeper understanding of how CMMI appraisal models influence and enhance organizational performance, thus providing valuable insights for both academia and industry. Therefore, this paper aims to cover this academic gap.
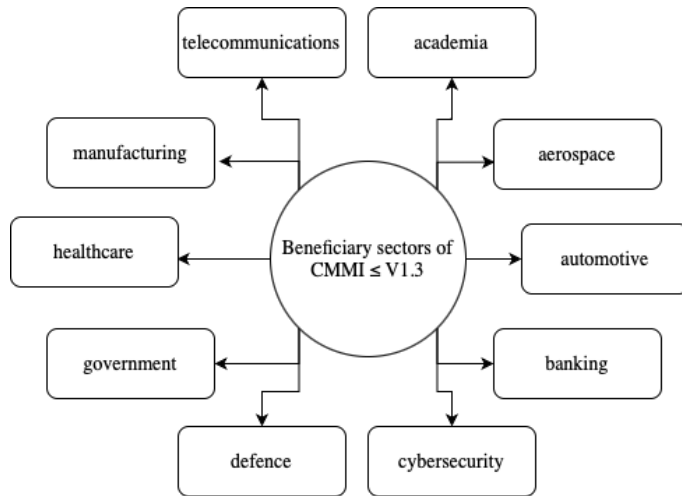
Figure 1. CMMI up to V1.3 footprint in the industry (Source: Authors' own contribution)

In this context, this paper aims to explore the contemporary applications of CMMI following the release of CMMI Version 2.0 in 2018. This paper will examine how organizations have chosen to use version 2.0 to deliver value and the challenges posed by its adoption in the industrial landscape.

Research questions development

Table 2. Research questions (Source: Authors' own contribution)

Research Questions	Motivation for Research Question
RQ1: How is the CMMI v2.0 model used to support organizational performance?	Understand how CMMI v2.0 contributes to modern organizations' performance.
RQ2: What are the challenges with the CMMI v2.0 model?	Get a better overview of organizations' challenges when using the CMMI v2.0 model.
RQ3: Which industries benefit from using the CMMI v2.0 model?	Identify industries where CMMI v2.0 has been used since its publication.

This study aims to identify how organizations have been using the Capability Maturity Model Integration (CMMI) appraisal model to further their organizational performance

in their chosen field of activity. As the most recent published version is CMMI v2.0, this study will focus on papers published from 2018 to the present day, when the current version was published. The three research questions (RQ) and the motivation behind them are presented in Table 2. The overall purpose of the research questions is to understand the value brought by CMMI v2.0.

In the context of this paper, modern organizations are considered to be structures (public, private, educational, etc.) focused on providing value to their customers.

Review protocol

This section describes the steps undertaken to conduct this research paper's analysis. For the purpose of this research, a systematic literature review has been performed. The research has been modeled based on similar works performed in the field of organizational maturity models (Kitchenham & Charters, 2007; Saavedra et al., 2017; Santos, Pimenta & Nobre, 2007) and adapted to the context of this paper.

Table 3. PICO search model adaptation (Source: Authors' own contribution)

Search elements	Description	Search terms
P	**Q: What are the categories of entities which will be considered?** A: The elements of this study are represented by CMMI-related terms.	"Capability Maturity Model Integration" OR "CMMI" OR "CMMI 2" OR "organizational maturity model" OR "organizational models" OR "maturity profile"
I	**Q: What will be considered for evaluation?** A: The element is represented by the component of organizational performance initiatives.	"organizational performance" OR "performance initiative" OR "organizational maturity model" OR "proposed model"
C	**Q: What search elements will support the comparison of the results?** A: This paper does not consider a comparison analysis, so this aspect will not be considered for research here.	N/A
O	**Q: What kind of outcomes are expected to result from this research?** A: The results are expected to include documentation and descriptions of how the CMMI v2 model has been considered concerning organizational performance initiatives.	"describe" or "description" OR "analysis" OR "experiment" OR "result" OR "value" OR "outcome"

The research starts by mapping the keywords used to identify the papers in scope for this systematic literature review. This activity follows the methodology proposed by Santos, Pimenta, and Nobre (2007), which relies on the PICO (Population –

Intervention – Comparison – Outcomes) search model. The terms that are selected for this paper use a structure that links all the elements of PICO as follows: "P" AND "I" AND "C" AND "I." The main keywords identified for this study are "Capability Maturity Model Integration," "CMMI," and "organizational maturity model," as well as their related synonyms and other associated terms. The motivation and complete list of terms for the search criteria are represented in Table 3. The term "CMMI" represented a challenging acronym as it was discovered during the search that it is widely used in multiple fields such as medicine, where it can refer to "Centers for Medicare and Medicaid Services," wireless communication, where it stands for "covariance matrix of malicious interference," optics, where it can mean "compact common mirror silicon photonic Michelson Interferometer," or in Internet of Things (IoT) networks, where I can be used to refer to "circular multirelay multiple-input multiple-output interference channel." Due to this complexity, multiple papers had to be analyzed in-depth to ensure the CMMI acronym was relevant to this paper's research.

After the search terms were identified, the next step was to define the inclusion and exclusion criteria. The model proposed by Meline (2006) was used for this activity. The criteria included an even balance of items to support curating the overall search. All the defined criteria can be found in Table 4.

Table 4. Research inclusion and exclusion criteria
(Source: Authors' own contribution)

Item	Criteria description	Inclusion/exclusion item
1	Is the publication year between 2018 (when CMMI v2 was launched) and the present time?	Inclusion
2	Is the publication in a language that is known to the reader of the work?	Inclusion
3	Does the work specifically mention that "CMMI v2" was considered for the work?	Inclusion
4	Is the acronym "CMMI" used with a meaning other than "Capability Maturity Model Integration"?	Exclusion
5	Is this a duplicate work?	Exclusion
6	Is the source of the publication from a reliable source?	Exclusion

The third step consists of assessing the quality of the selected publications. For this purpose, the models presented by Williams and Carver (2010), and Rouhani, Mahrin, Nikpay, Ahmad, and Nikfard (2015) were used. The quality questionnaire can be found in Table 5.

Table 5. Quality assessment questionnaire for this research
(Source: Authors' own contribution)

Item	List of quality assessment questions
1	Is the CMMI model described in detail?
2	Is the problem statement clearly described?
3	Are the constraints and limitations of the publication mentioned clearly?
4	Is the value to the publication sector described clearly?

5	Do the publication findings contribute to the topic of this research?
6	Is CMMI version 2.0 mentioned explicitly or only implied?
7	Is the research methodology easily reproducible?

The fourth step represented identifying the sources where the elements were searched. The research did not concern any specific industry, so the online platform "Web of Science" was considered a starting point. From here, articles were identified in the following digital platforms and considered for further analysis: IEEE Xplore, Scopus, Wiley Online Library, Emerald Insights, MDPI, ProQuest, ScienceDirect, and Springer. Articles accessible in grey digital libraries such as Google Scholar or ResearchGate have also been considered, with the condition that the paper with the same title from the same author(s) was present in any academic digital libraries.

While the research is intended to be as accurate as possible, a series of constraints and limitations have been identified and need to be considered for the interpretation of the results. First off, the language constraints. Although more than 500 research papers have been identified based on the search criteria, not all of them could be read and analyzed thoroughly because they are in a language unknown to the researcher. Secondly, the presence of "CMMI" acronyms with a different meaning than "Capability Maturity Model Integration" or with only the acronym mentioned, not the full description. Where such papers were identified, it was concluded that excluding them from this research paper would be adequate, as there is a high chance of inaccurate interpretation. Thirdly, the delimited range where research papers were searched could also constitute a risk factor. Even though the most reliable academic online databases were searched, there is the possibility that not all relevant material sources were combed for papers that matched this paper's research protocol.

The online databases were accessed in the final step, and publications were analyzed against the abovementioned criteria between July and August 2023. The answers to the three research questions are described in the "Results" section. Further insights are provided in this qualitative research paper's "Discussions" section. Based on the initial keyword search criteria, more than 500 publications have been identified as relevant. After applying the remaining criteria described in this section, only 13 publications matched the requirements for continuing the in-depth analysis. Since their publication, these 13 studies have summed up 80 citations in other reference works.

Results

While the pool of articles validated against the chosen criteria is smaller than initially expected, the chosen publications offer valuable insights regarding the adoption of the CMMI Version 2.0 model. To simplify the analysis, the immediate findings of this paper are structured in sub-sections for each research question, followed by other notes resulting from the analysis.

RQ1: How is the CMMI v2.0 model used to support organizational performance?

The analyzed texts have displayed various initiatives organizations undertake to improve their processes, leading to increased performance. According to Henríquez & Moreno (2021), there is evidence that CMMI v2.0 is being used to deliver

organizational performance results through the continuous alignment with agile concepts and DevOps best practices. Similar results were discovered in the research from Sanjurjo, Pedreira, García, and Piattini (2020), who showed that when recommendations and best practices from CMMI v2.0 and recognized standards are adapted to the demand of the organization, the result can lead to the development of fit for purpose frameworks such as that of MMBDO, Maturity Model for Business DevOps. As such, this adaptation of a CMMI v2.0 & DevOps can support organizations in aligning their business processes and practices with industry standards. In another case (Al-Matouq, Mahmood, Alshayeb, & Niazi, 2020), CMMI v2.0 has proven to be a reliable framework for developing a cybersecurity model known as the Software Design Maturity Model (SSDMM). Several of the publications (Degerli, 2020a; Fuentes & Jenkins, 2022) recognize the value brought by CMMI v2.0 in organizations elevating their performance across multiple aspects, such as the streamlining of practical tools, templates aimed to facilitate a transition to the new model or to improve facilitation of complex projects, in the area of communication, coordination, organizational relationship, etc, which are all important aspects of a mature process structure. Also, in the context of organizational performance, CMMI v2.0 has shown to play an important role when it comes to optimizing project-associated costs, which in turn leads to higher chances of projects being carried out successfully without bringing additional risks to overall organizational performance (Degerli, 2020b). Another example in this area comes from research performed by Henríquez, Moreno, and Gutiérrez (2022), who present CMMI v2.0 training as a critical success factor for supporting organization performance in tasks related to project planning, alignment of organizational goals, and responding to the challenges posed by VUCA-driven (Volatility – Uncertainty - Complexity - Ambiguity) factors. Given its broad applicability, this framework version could deliver value to governance and management processes as they transition to technologies that are part of the Industrial 4.0 case studies (Ariffin & Ahmad, 2021). Referring to organizational processes as a whole, analyzed studies (Henríquez, Moreno, Calvo-Manzano, & Feliu, 2021; Sundaram & Suresh, 2023) have pointed out that CMMI v2.0 is used through organizations at different levels to streamline operational processes in various industries, as well as contribute to better integration to achieve organizational performance.

Out of the 13 selected studies, 10 highlighted examples of how CMMI Version 2.0 is being adopted and adapted by organizations to further process optimization and the organizational performance objectives of the entities to which they relate.

**RQ2**: What are the challenges with the CMMI v2.0 model?

While CMMI Version 2.0 has been shown to bring benefits to organizations and their processes, it is not tailored to meet all the available demands. In some cases, organizations tend to miss out on the benefits that come from the adoption of Software Process Improvement (SPI) in relevant industries due to there being a gap in benchmarking exercises (Hani, Khan, Amjad, Jhanjhi, Latif, & Zia, 2022). In organizations that have previously used older CMMI versions, which were not aligned to contemporary Agile practices, a challenge has been noticed with embedding the recommendations of the new version, particularly from CMMI-DEV2.0. The lack of Agile-inclusive guidelines is a caveat that would need to be addressed either centrally by ISACA or by each organization individually (Henríquez, Calvo-Manzano, Moreno, & San Feliu, 2022). In a study conducted by the same core group of authors as above

(Henríquez, Moreno, Calvo-Manzano, San Feliu, & Scheihing, 2023), the challenges posed by the adoption of the CMMI v2.0 were also noticed in small and medium enterprises which operate through an Agile model. As a result, this group of organizations often struggle and do not benefit from the full potential of this framework.

**RQ3**: Which industries benefit from using the CMMI v2.0 model?

Since its first release in 2002 as CMMI Version 1.1., this Maturity Model has had an impact on a wide net for industries, as also shown in Fig. 1., yet in the collection of articles selected for this study, only a handful of industries updated or adapted for the first time this standard. This update of industries is represented in Figure 2. The industries that benefited from CMMI up to and including Version 1.3 are strikethrough, new industries are marked with green, and depicted sectors in both versions stay the same as in Figure 1. Another observation in this case is that there tends to be a micro-adoption of the framework, which means that instead of looking at the industry itself for improvement, the tendency is to consider CMMI for adoption at the process or department level, such as software development processes, cybersecurity models, project management units, learning and development areas, and DevOps practicing-units.
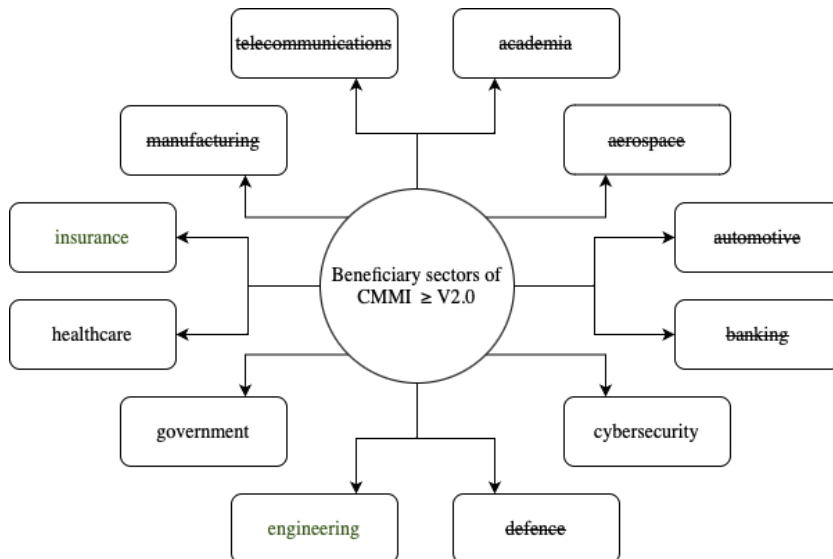
*Figure 2. CMMI V2.0 footprint in industries (Source: Authors' own contribution)*

Discussion

The systematic literature review system was used to provide answers to the three research questions in scope for this analysis. From the over 500 papers identified and checked against set criteria, only 13 were selected for further analysis. Beyond the research questions, the selected studies showed that CMMI continues to be of great interest, with publications in databases such as IEEE Xplore, Elsevier, PeerJ Computer Science, Springer, and Wiley Online Library (Figure 3).
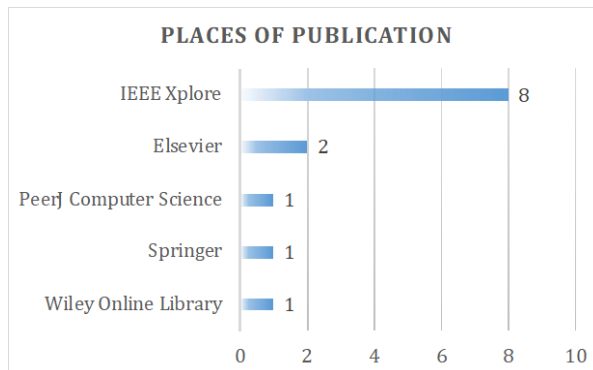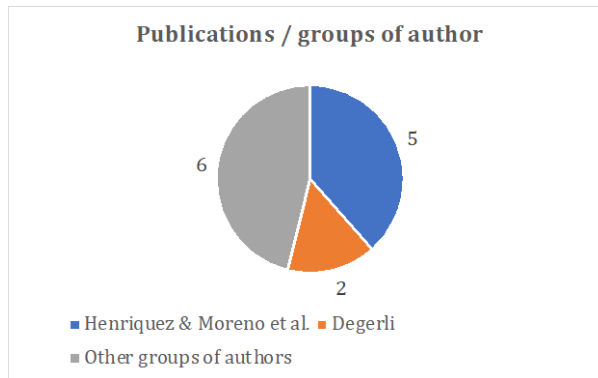
Figure 3. Publication locations (Source: Authors' own contribution)

While the current version of CMMI was released in 2018, the first papers that reference V2.0 in clear have only started appearing in 2020, as shown in Figure 4. Research into the 500 papers revealed that there is still a tendency to benchmark or refer to Version 1.3 or earlier when preparing academic articles. A possible cause might be the broader availability of publications, open access to journals that provide the underlying documentation, and further maturity expectations from organizations before deciding to embark on a journey of adoption or update of V2.0. As the results from RQ1 have shown, there is a demand for adopting and aligning V2.0 to Agile frameworks, which is stifled by the lack of specific Agile guidelines.
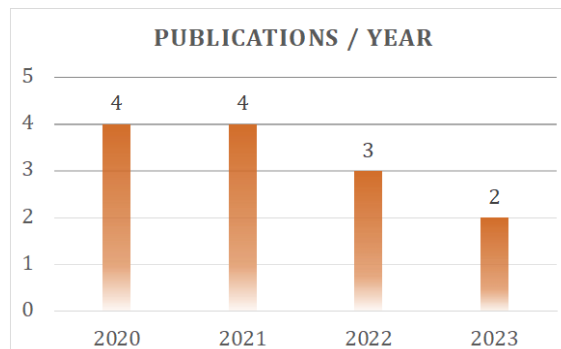

Figure 4. Publication/year in scope for the study
(Source: Authors' own contribution)

Insights into authors also revealed that groups of authors are performing dedicated research for Version 2.0 (Figure 5), with the majority of them being published in English, immediately followed by Spanish as the publication language (Figure 6).

Publications / groups of author

5

6

2

- Henriquez & Moreno et al. ■ Degerli
- Other groups of authors

Figure 5. Publications/groups of authors (Source: Authors' own contribution)

Publication languages

Spanish
15%

English
85%

■ English ■ Spanish
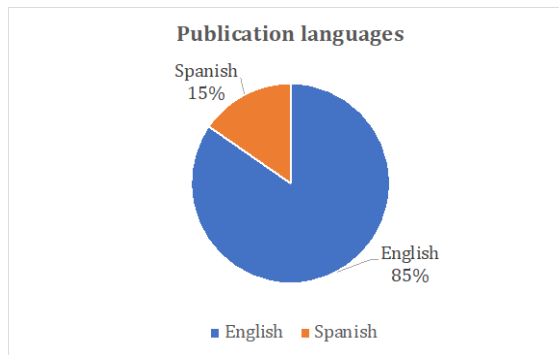
Figure 6. Publication languages (Source: Authors' own contribution)

The analyzed publications also revealed a series of gaps in the literature that can make the object of future research. This includes the evaluation of Agile environments using CMMI and their adoption journey. Another option is a comparative analysis with other process improvement models for the industries where Version 2.0 has already been adopted to prepare models for assessing strengths, weaknesses, opportunities, and threats, eventually resulting in a best practice guide. The third is a study on maturity models and organisational culture. This third point could explore how the two aspects influence one another and how cultural alignment can position itself as a critical success factor for CMMI adoption or update, depending on the context.

Conclusions

In conclusion, this research paper has highlighted the benefits of organizations integrating CMMI v2.0 in their organizational performance initiatives, the challenges brought forth by Version 2.0, and the industries in which studies concerning CMMI Version 2.0 have been performed. The discussion has shed light on several demographic aspects and revealed research gaps that can be explored to understand this Maturity Model better. In this regard, the Capability Maturity Model Integration continues to be a solid point of reference for organizations looking to improve their processes and thus reach organizational performance.

From a technical perspective, this paper provides insights into the techniques for performing a Maturity Model analysis and how to gain insights by conducting a

systematic literature review. From a. content point of view, the topic of value offering for organizations looking to implement/update CMMI Version 2.0 in their practices by analyzing success stories and providing ideas on how to integrate this framework in their existing processes, as well as the challenges which might be encountered along the way. The study's major limitations have been assessed and reflected in the protocol review section, and it should provide future researchers with a starting point when exploring the benefits of the CMMI appraisal model.

Based on the available information from the Information Systems Audit and Control Association (ISACA, 2023), the study of CMMI is expected to draw more attention in preparing to release CMMI V3.0.

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