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Challenges in implementing free software in small and medium-sized enterprises in the city of Montería: a case study

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ABSTRACT

This study investigates challenges and opportunities in adopting free and open-source software (FOSS) in small and medium-sized enterprises (SMEs) in Monteria, Colombia. The research reveals that around 77.5% of SMEs prefer free software, yet surprisingly, 80% are unaware of the benefits of open-source licenses, with nearly 45% not adopting them due to lack of knowledge. Implementing FOSS in SMEs offers legal and economic advantages, including reduced software acquisition costs, compliance with data protection and privacy regulations, and fostering innovation. However, adoption barriers persist, necessitating further research for enhancing implementation in Colombian SMEs. Notably, Colombia's ethical framework for AI serves as a guide for ethical AI and open-source software deployment, aligned with sustainable development goals. This study highlights free software usage prevalence in Monteria's SMEs and critical factors hindering full adoption. Addressing challenges and leveraging potential benefits can improve efficiency, regulatory compliance, and contribute to sustainable development. Continued research in this field can promote broader and stronger implementation of FOSS in Colombian SMEs.

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1. INTRODUCTION

In recent years, the information and communication technology (ICT) sector has experienced significant growth in the use of free and open-source software (FOSS) [1]. This type of software is particularly attractive to small and medium-sized enterprises (SMEs) due to its freedom of use, duplication, modification, and distribution [2]. Its affordability and ability to adapt to the specific needs of each organization have driven an increase in its use globally [3]. In Colombia, SMEs represent 98% of the country's businesses and generate 80% of employment [4]. ICT can be an essential tool to improve the efficiency and productivity of these businesses; however, the cost associated with the acquisition and maintenance of commercial software can represent a barrier for many of them [5]. In this context, free software emerges as a viable solution.

The use of free software offers numerous legal benefits to SMEs [3], [6]. Firstly, it can minimize the risk of copyright and intellectual property violations, as it is usually distributed under licenses that allow the modification, distribution, and free use of the software [2]. Additionally, it can help SMEs comply with data

protection and privacy laws and regulations [7]. Many free software programs are designed to meet privacy and information security standards, which is crucial for SMEs that handle sensitive customer data [8]. Despite its benefits, the adoption of free software in Colombian SMEs remains low compared to other countries [9]. This study aims to analyze the relevance and impact of free software on SMEs in Montería, Colombia, in order to improve their competitiveness in the market. It also seeks to recognize the challenges and difficulties that Colombian businesses face when adopting free software and explore possible solutions. The manuscript is organized such that section 2 contains a detailed literature review and a description of the methodology used. The study results and a discussion of the findings are comprehensively presented in section 3. The paper concludes with section 4, where the conclusions and recommendations for future research are delineated.

2. METHOD

In order to analyze the state of the art in the implementation of free software in Colombian SMEs, a literature search was conducted in the Scopus database. The search string used was as follows:

("Free software" OR "Free software in SMEs") AND ("Information and communication technologies" OR "ICT" OR "Open source software" OR "Free software" OR "Open licenses" OR "Intellectual property") (All Fields) and 2018 or 2019 or 2020 or 2021 or 2022 or 2023 (Publication Years) and Article or Book Chapters (Document Types) and All Open Access (Open Access) and English (Languages).

Figure 1 shows the co-occurrence of keywords within the articles identified in the Scopus database using the search string [10], [11]. Table 1 shows the most common publication (MCP) and single country publication (SCP) for each country with more than 4 publications. The MCP refers to the number of articles in which the country appears as the corresponding author's country, while the SCP indicates the number of publications in which the country is the only country of the authors. In the case of Colombia, it can be observed that its scientific production is relatively low compared to other countries for the bibliometric findings of the implemented search string. Figure 2 presents a geographical visualization of scientific collaboration between countries.

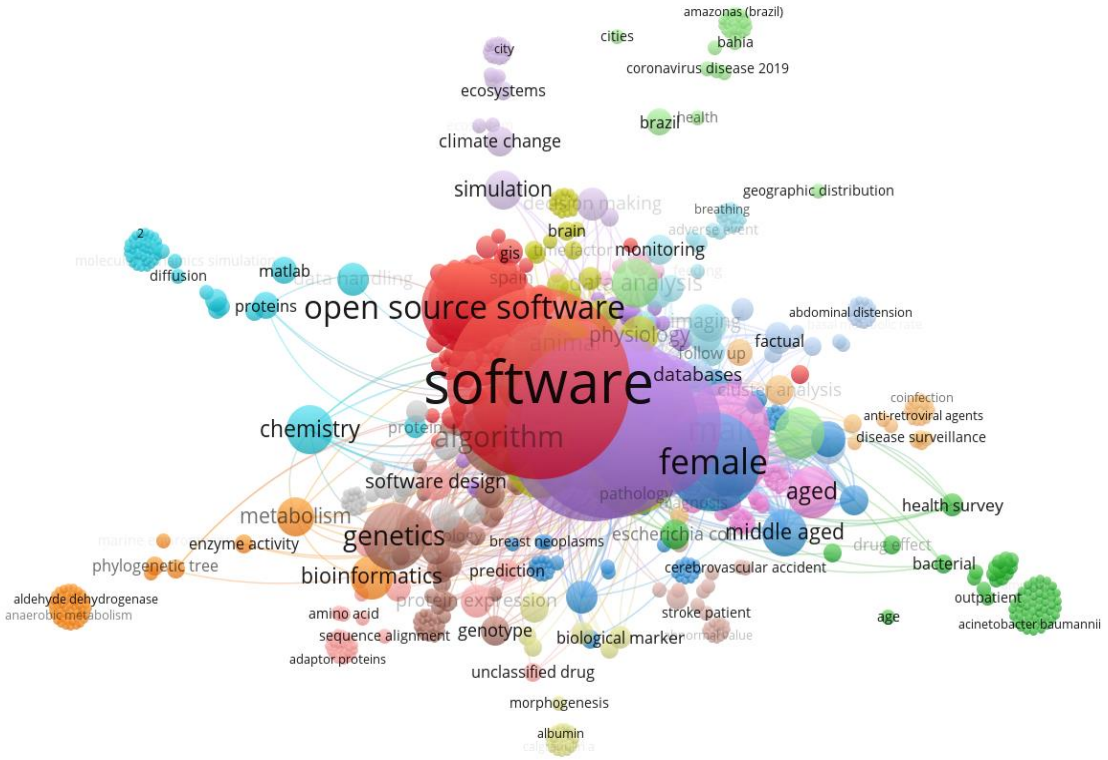

Figure 1. Co-occurrence of words

Table 1. Bibliometric analysis of MCP and SCP by country with more than 4 publications

Country	Articles	SCP	MCP
USA	55	48	7
Spain	49	42	7
Brazil	40	29	11
France	28	19	9
Germany	19	11	8
United Kingdom	18	9	9
Italy	17	12	5
China	14	12	2
India	11	8	3
Mexico	11	9	2
Japan	10	5	5
Netherlands	9	4	5
Poland	9	7	2
Sweden	8	4	4
Switzerland	8	5	3
Colombia	7	5	2
Greece	6	6	0
Portugal	6	4	2
Canada	5	4	1
Denmark	5	3	2

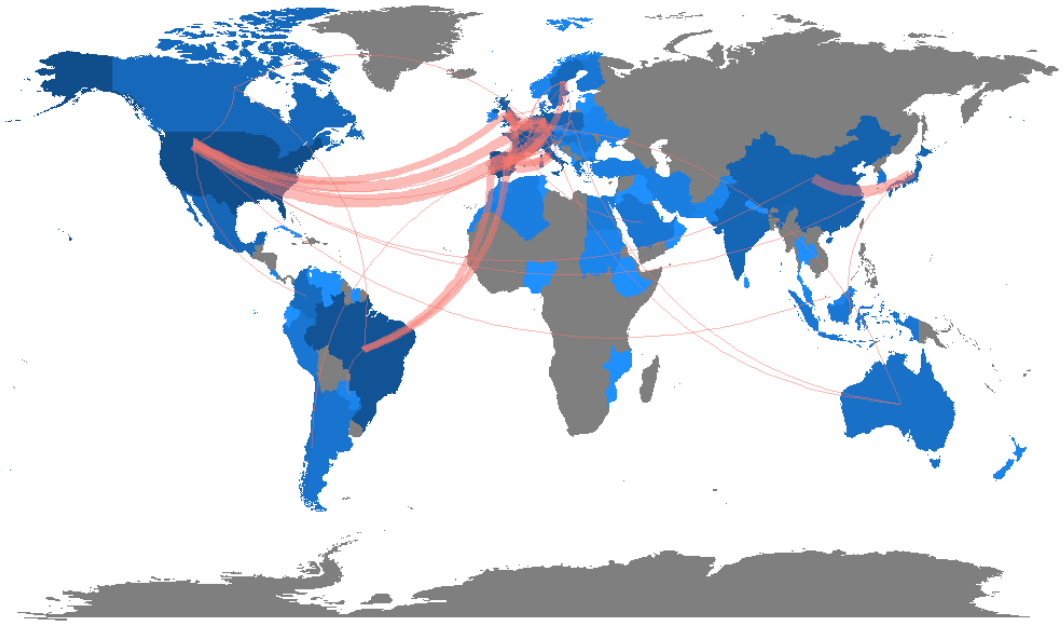

Figure 2. Countries collaboration world map

The study on software adoption in SMEs in Montería reveals a scarce scientific production compared to other countries, highlighting the need to increase research in this area. This represents an opportunity to promote the use of open-source software in SMEs. The aim of this research is to analyze the relevance and impact of open-source software on SMEs in Montería, Colombia, in order to improve their competitiveness in the market, as well as to recognize the difficulties and challenges that Colombian companies face when adopting open-source software and to explore possible solutions. Table 2 presents a selection of fundamental and highly relevant works in the field, identified through the systematic literature review of this study. These works, recognized as key references, can provide a solid starting point for future studies in this area.

The comparative analysis presented in Table 2 focuses its attention on several significant research studies on the adoption and implementation of technology by SMEs. These studies provide a broad and diverse view of the relationship between SMEs and technology, from the adoption of enterprise resource planning (ERP) systems to the use of chatbots and the prioritization of investments in information security. The subsections below provide the methodology used in this research.

Table 2. Comparative analysis of research studies on SMEs' technology adoption and implementation

Paper title	Objective	Main findings	Suggested improvements	Contributions	Relevance	Future implications
The Role of Government Support in SMEs' Adoption of Sustainability [12]	Evaluate the impact of government support on SME sustainability	Low impact of government support on sustainability adoption in SMEs	Need to increase awareness about support programs	Identification of the disconnect between SMEs and government support programs	Relevant for public policy and business management	Influence on governmental policy design
Antecedents and Impacts of Enterprise Resource Planning System Adoption among Jordanian SMEs"[13]	Analyze enterprise resource planning (ERP) adoption and its effects in Jordanian SMEs	Technology-organisation-environment (TOE) factors, except compatibility, are significant antecedents of ERP adoption	Expansion of the focus beyond Jordanian manufacturing SMEs and TOE variables	Validated model of ERP adoption	Enhancement of competitiveness and performance in SMEs	Guide future ERP adoption research
A hermeneutic analysis of critical success factors for Enterprise Systems implementation by SMEs [14]	Refine critical success factors (CSFs) for enterprise systems (ES) implementation in SMEs	Three distinct CSFs and eight frequently cited for SMEs	Expansion of literary review and of qualitative selection and review	Consolidated list of CSFs for ES implementation in SMEs	Useful for prioritizing resources and efforts	Influence on future research and case studies of ES implementation
Chatbot for SMEs: Integrating Customer and Business Owner Perspectives [15]	Explore chatbot perceptions in SMEs	Simple and automatic chatbots were perceived as more anthropomorphic and easier to use	Improvement of chatbots' anthropomorphic features and expansion of experimental design	Emphasizes the need for chatbots that promote utility and enjoyment	Relevant for the design and implementation of chatbots in SMEs	Guide for future research on chatbot design and use
Information security investment prioritization using best-worst method for small and medium enterprises [16]	Prioritize security investments in SMEs	Network protection was the priority investment	Clearer differentiation in the weighting of security features	Proposal of a level classification instead of a ranking	Helps SMEs to decide on security investments	Influence future SMEs security investments
Technology Organization Environment Framework in Cloud Computing [17]	Apply TOE model to understand cloud adoption in SMEs in Bangladesh	All factors of the TOE model are positive for cloud adoption	Inclusion of more issues related to cloud adoption	Checklist for cloud adoption	Informs decisions on cloud adoption in SMEs	Implications for future research and practices on cloud adoption
Influence of SME Characteristics on ERP [18]	Analyze the influences of SME context in ERP implementation	SME characteristics influence ERP adoption	Increase use of business process redesign (BPR)	Identification of influential characteristics for ERP implementations	Reference for SMEs wishing to implement ERP	Useful for future research and ERP adoptions in SMEs

2.1. Study design and sample size

This descriptive study, with a quantitative approach, was conducted in Monteria, Colombia, with the aim of analyzing the adoption of open-source software in SMEs. Considering the statistical distribution of the 170 service-sales SMEs, the stratified random sampling method with proportional allocation was used [19]. To determine the representative sample size with a 90% confidence level, in (1) was used:

$$n_i = \frac{\sum W_h P_h Q_h}{\frac{E^2}{Z^2}}; n = \frac{n_i}{1+\frac{n_i}{N}} \quad (1)$$

Where:
Wh=Proportion of companies in the selected sector
Ph=0.5 (probability of meeting the study condition (use of free software)

Qh=0.5 (probability of not using free software)
E=0.098 (sampling error)
Z=1.65 (confidence percentile of the study sample)
N=Total number of selected companies
ni=Sample for infinite population
n=Sample adjusted to the selected population

2.2. Data collection instruments

Two measurement instruments were used in this study, both demonstrating high internal consistency, as indicated by their Cronbach's Alpha values [20]. The first instrument consisted of 10 questions focused on the software applications used in SMEs and their classification according to the principles of software engineering. The second instrument consisted of 10 questions designed to assess the understanding of FOSS, its organizational advantages, and potential obstacles to its implementation. To calculate Cronbach's Alpha, in (2) was used:

$$\propto = \frac{K}{K-1}\left[1 - \frac{\sum Vi}{Vt}\right] \quad (2)$$

Where:
α=Cronbach's Alpha
K=Number of items
Vi=Variance of each item
Vt=Total iariance

2.3. Data collection procedure

The measurement instruments were applied to the selected SMEs. The first instrument was designed to understand the types of software applications used in SMEs and their classification. The second instrument was used to assess the understanding of FOSS and its implications in SMEs. The data collected from these instruments were then analyzed using GNU PSPP (hereafter referred to as "PSPP"), a free software alternative to SPSS [21].

2.4. Data analysis

The data collected from the measurement instruments were analyzed using Cronbach's Alpha to assess the internal consistency of the instruments. The results of the analysis were then used to evaluate the understanding of FOSS and its implications among SMEs. The reasons for not using FOSS licensed applications were also identified based on the results obtained through the PSPP software [21].

2.5. Software comparison

A comparison was undertaken to understand the potential of FOSS as alternatives for SMEs. Specifically, we compared the applications used by SMEs with FOSS projects that possess similar functional features, a robust support community, and sufficient documentation. The primary objective of this comparison was to pinpoint software alternatives that are free or open-source and could effectively replace the current applications used by SMEs.

2.6. FOSS implementation plan

Based on the findings of the study, a well-defined and structured plan for adopting FOSS was proposed. This plan outlined nine distinct stages, accompanied by their corresponding controls and associated activities. The stages included needs identification, solution evaluation, solution selection, implementation plan development, employee training, software installation, software testing, performance monitoring, and continuous improvement.

2.7. Legal and regulatory aspects

The study delved into the considerations of implementing FOSS, paying keen attention to both legal and regulatory dimensions. It was imperative to ensure compliance with international standards and international law, especially in the realms of ICT and software. Additionally, the study made certain to align with Colombian ICT and software regulations and legislation.

2.8. Promotion of emerging technologies

The study emphasized the importance of integrating emerging technologies within the realm of FOSS. Key technologies related to the fourth industrial revolution were highlighted, such as artificial

intelligence (AI)/machine learning, big data, and the internet of things (IoT). These technologies play a pivotal role in modern software implementation and advancement.

3. RESULTS AND DISCUSSION

3.1. Sample size

In the process of the study, we sought to determine an appropriate sample size that would best represent the study population. It was ascertained that a representative sample size should consist of 50 SMEs from the city of Montería. This decision was based on the calculation performed using (1).

3.2. Validation of the instruments

Table 3 summarizes the Cronbach's Alpha values from in (2) for each of the measurement instruments used in this study, highlighting the high internal consistency of both questionnaires in the evaluation of the constructs of interest.

Table 3. Cronbach's Alpha results for measuring instruments

Measurement instrument	Number of questions	Cronbach's Alpha
Software applications and classification in SMEs	10	0.92
Understanding of FOSS and its implications	10	0.89

The first instrument, which consists of 10 questions about the software applications used in SMEs and their classification according to software engineering, obtained a Cronbach's Alpha of 0.92. This value indicates high internal consistency, suggesting that the questions in the first instrument are effectively measuring the underlying construct related to the classification of software applications used in SMEs. The second instrument was specifically designed to gauge the understanding of FOSS among SMEs. Comprising 10 questions, it addressed both the organizational advantages of the software and the potential challenges in its implementation. A Cronbach's Alpha of 0.89 was observed for this instrument, signifying a high internal consistency. This suggests that the questions effectively measure the intended construct concerning the comprehension of FOSS and its role in SMEs.

3.3. Open-source software knowledge

The measurement instrument was applied to the selected SMEs. The results showed that 75% of them confuse the term "open-source software" with "free software" on the other hand, 10% were unaware of the term, and 12.5% claimed to be familiar with it, as illustrated in Figure 3.

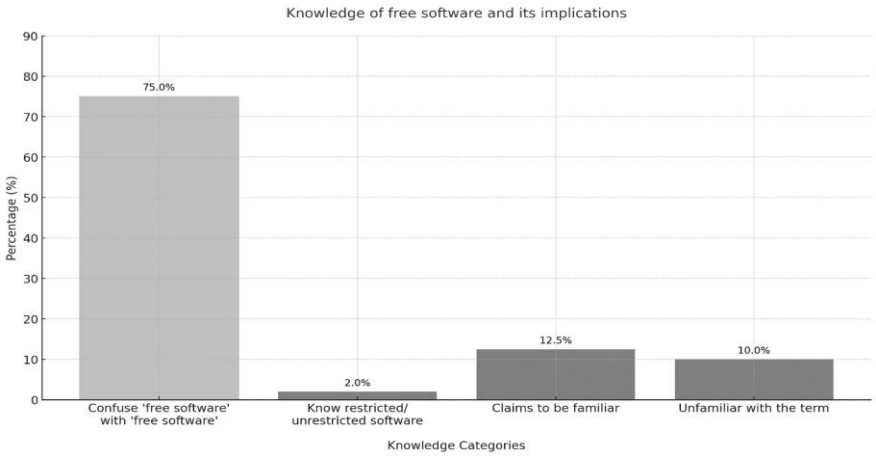

Figure 3. Knowledge of free software and its implications

3.4. Reasons for not using free/open-source licensed applications

Based on the results obtained through the PSPP software, which analyzes the data collected from the measurement instrument applied to SMEs, the following findings were observed: 45% of SMEs are unaware of the use of open-source licenses, 27.5% exhibit resistance to change, 20% express a lack of trust, and 7.5% point to the absence of adequate support. Figure 4 illustrates these proportions in detail.

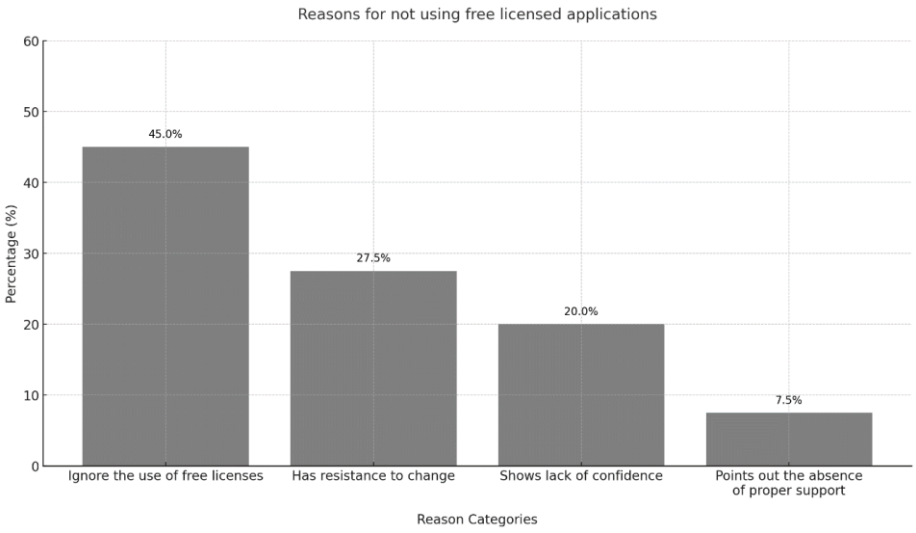

Figure 4. Reasons for not using free licensed applications

In this study, it was found that 45% of SMEs are unaware of FOSS. Globally, the adoption and knowledge of FOSS can vary significantly depending on factors such as business culture, resource availability, and government support, among others. This situation highlights the lack of knowledge that SMEs have regarding the advantages offered by the use of open-source licensed applications. As evidenced in Figure 3, a high percentage of SMEs are still unaware of the benefits associated with FOSS, which underscores the need to promote and disseminate information about these types of technological solutions in the business environment [22]. This finding aligns with the limited awareness that SMEs possess regarding the advantages linked to utilizing open-source licensed applications. The obtained results indicate a significant proportion, specifically 80%, exhibiting a lack of understanding regarding the benefits offered by this software category. Furthermore, the study revealed that a notable 92.5% of SMEs expressed their willingness to adopt applications with an open-source license, with only a marginal 7.5% showing no interest in pursuing such implementation. Figure 5 shows, in orange, the applications used by SMEs, previously categorized into groups such as operating systems, databases, services, office suites, application development, and utilities. Additionally, in green, it shows FOSS projects with similar functional features, a robust support community, and sufficient documentation to replace these applications.

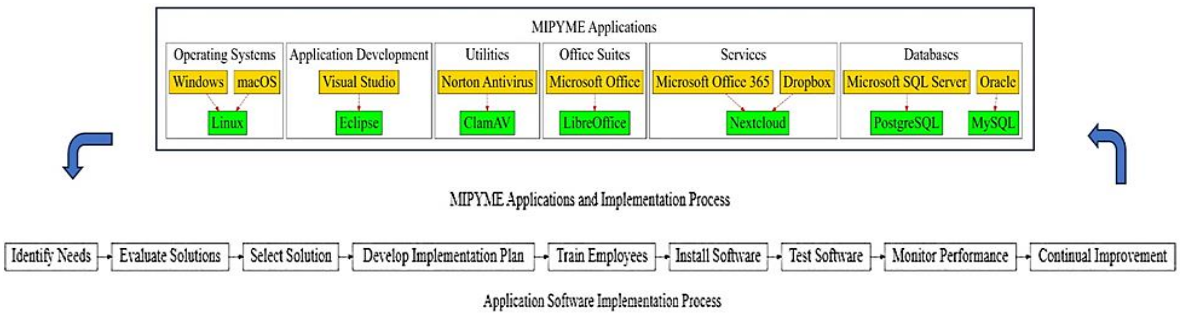

Figure 5. Comparison of SME applications and their free software alternatives

As a contribution of this study, a well-defined and structured plan for adopting FOSS is proposed. This plan, illustrated in Figure 5, offers substantial support to the implementation process by outlining nine distinct stages, accompanied by their corresponding controls and associated activities [23]–[25]. Figure 5 presents a comprehensive overview of the software implementation stages, which include:

a. Identify needs: identify and understand the needs and requirements of application software in the organization.
b. Evaluate solutions: research and analyze various software solutions available on the market that can meet the identified needs.

c. Select solution: choose the most suitable software solution in line with the organization's needs and budget.
d. Develop implementation plan: create a detailed plan outlining the necessary steps, timelines, and resources required for the implementation of the selected software.
e. Train employees: provide employees with the necessary training to effectively use and maintain the new software.
f. Install software: install the selected software on the organization's computer systems.
g. Test software: verify that the software functions correctly and meets the requirements established in the needs identification phase.
h. Monitor performance: monitor and evaluate the software's performance in the organization to ensure the intended objectives are met.
i. Continual improvement: identify and apply improvements to the software and its related processes to ensure optimal functionality and adaptability to the organization's changing needs.

The research conducted in Monteria, Colombia, on FOSS adoption in SMEs has yielded significant findings. Data collected indicates that 77.5% of SMEs opt for free software irrespective of conditions, 80% lack awareness regarding the benefits of open-source licenses, and 45% refrain from adopting FOSS due to limited knowledge [26]. These findings highlight the existing barriers to FOSS adoption in Colombian SMEs, despite its increasing popularity. However, implementing this software in SMEs can bring various legal advantages, such as reducing copyright and intellectual property infringement risks, lowering acquisition and licensing costs, and ensuring compliance with data protection and privacy regulations [1]. Moreover, it can stimulate innovation and technological development, creating new business opportunities and fostering long-term growth [27], [28].

SMEs in Colombia contribute to 98% of the country's businesses and generate 80% of the jobs [4]. Despite their economic significance, these companies face challenges in maintaining competitiveness. Information and ICT can enhance efficiency and productivity for Colombian SMEs; however, the cost of acquiring and maintaining commercial software poses a hindrance for many of them [29], [30]. Hence, FOSS presents a viable solution due to its affordability and adaptability to each company's specific needs [1], [26]. Notably, research on FOSS adoption in Monteria's SMEs has limited scientific output compared to other countries, underscoring the need for further research in this area [5], [23], [29], [31]. This represents an opportunity to enhance FOSS implementation in SMEs. Therefore, conducting research is crucial to assess the relevance and impact of FOSS on Monteria's SMEs in Colombia, improve their market competitiveness, identify barriers and challenges in its adoption, and explore potential solutions.

Implementing FOSS in Colombian SMEs can reduce costs, improve efficiency and productivity, foster innovation and technological development, and ensure compliance with data protection and privacy regulations. However, persistent obstacles necessitate research promotion to facilitate greater adoption in Colombian SMEs [22]. In line with Figure 5, Figure 6 presents a detailed and structured view of the FOSS implementation process, integrating legal and regulatory aspects while promoting emerging technologies crucial in the current context of innovation and technological development [32]. Figure 6 emphasizes the significance of key performance indicators (KPIs) in evaluating each stage's performance, facilitating the identification of areas for improvement and optimizing FOSS utilization. By addressing technical and legal aspects and promoting emerging technologies, the flowchart offers a comprehensive perspective to ensure successful and sustainable FOSS implementation in an organization.

The following is an explanation of the flowchart provided in Figure 6, which covers three main areas: FOSS implementation (explanation presented in the results section with Figure 5), legal and regulatory aspects, and promotion of emerging technologies. FOSS implementation: i) identify needs; ii) evaluate solutions; iii) select solution; iv) develop implementation plan; v) train employees; vi) install software; vii) test software; viii) monitor performance; and ix) continual improvement. Legal and regulatory aspects [33], [34]: i) international standards: ensure compliance with international standards related to the implementation of open-source software; ii) international law: verify that the implementation of FOSS complies with applicable international laws and regulations; iii) international ICT and software law: abide by international laws and regulations related to ICT and software; and iv) Colombian ICT and software regulations and legislation: comply with applicable Colombian laws and regulations in the field of ICT and software. Promotion of emerging technologies [35]: i) Industry 4.0: encourage the use of emerging technologies related to the fourth industrial revolution; ii) AI/machine learning: promote the adoption of AI and machine learning in the implementation of FOSS; iii) big data: incentivize the use of big data technologies in the implementation of FOSS and iv) IoT: drive the integration of IoT technologies in the implementation of FOSS.

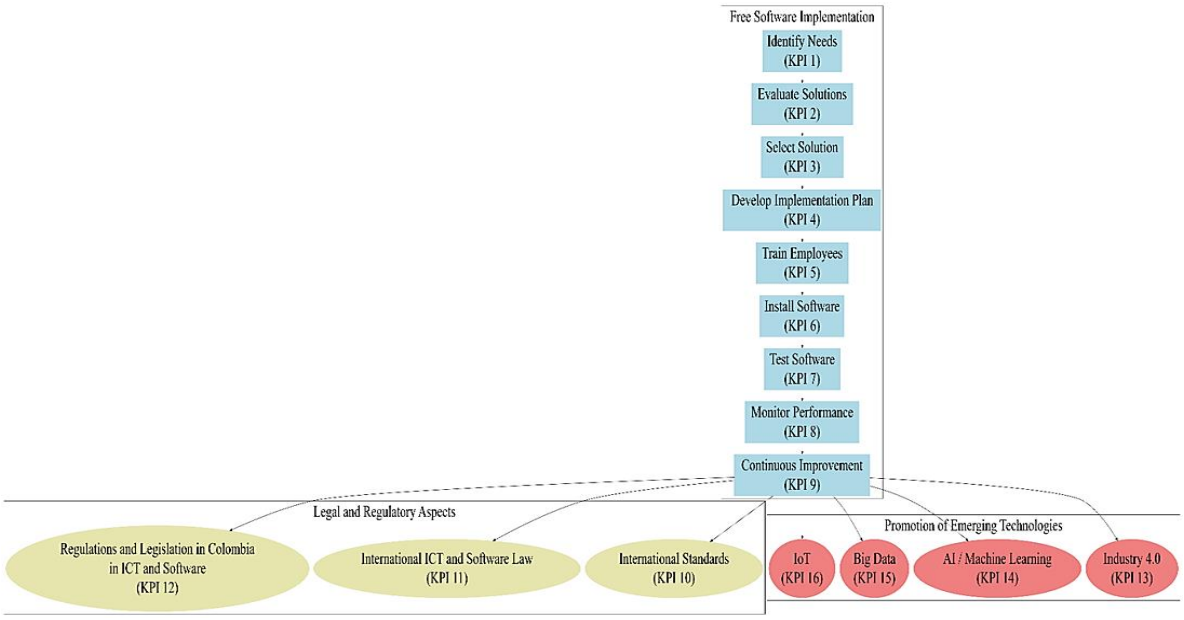

Figure 6. FOSS implementation process and its interrelation with legal aspects and emerging technologies

This study provides a detailed view of the understanding and adoption of FOSS among SMEs in Montería, Colombia [4]. In a context where SMEs represent 98% of all businesses and generate 80% of employment, the adoption of FOSS emerges as a viable strategy to improve efficiency, productivity, and competitiveness. Although previous research has been conducted on FOSS adoption in different contexts as seen in Table 2, this study is one of the first to explore this topic in the context of SMEs in Montería, a region that has received little attention in the existing literature.

Despite the potential benefits of FOSS, the study reveals a significant lack of awareness and understanding about this type of software. It was found that 75% of SMEs confuse the term "open-source software" with "free software", and 45% are unaware of the use of open-source licenses. This lack of knowledge represents a significant barrier to the adoption of FOSS. However, despite this lack of awareness, a notable 92.5% of SMEs expressed their willingness to adopt open-source licensed applications. The study also identified several reasons why SMEs do not use free/open-source licensed applications, including lack of knowledge about the use of open-source licenses (45%), resistance to change (27.5%), lack of trust (20%), and absence of adequate support (7.5%). To overcome these barriers, the study proposes a well-defined and structured plan for the adoption of FOSS. This plan, consisting of nine distinct stages, provides substantial support to the implementation process, providing corresponding controls and associated activities.

The Colombian government, through the Ministry of ICT, has been actively promoting the adoption of FOSS among SMEs [36]. Through initiatives such as the national online government strategy and the national free software program, the government has demonstrated its commitment to fostering open-source software as a viable option to improve competitiveness and drive innovation across all business sectors [37], [38]. In addition, frameworks like Colombia's ethical framework for AI can serve as a valuable guide for businesses looking to implement AI technologies and open-source software in the country [39].

Despite the lack of awareness and understanding, the study reveals a significant opportunity for FOSS adoption among SMEs in Montería. The majority of surveyed SMEs expressed their willingness to adopt open-source licensed applications, indicating a potential market for FOSS providers and an opportunity for SMEs to benefit from the cost savings, flexibility, and innovation potential that FOSS can offer. Finally, the study underscores the importance of support and guidance in the FOSS adoption process. For SMEs considering FOSS, a structured approach, like the plan proposed in Figure 5, could be beneficial.

4. CONCLUSION

From the study conducted in Montería, Colombia, several key findings were identified regarding the adoption of open-source software in SMEs. It was observed that most of the SMEs surveyed in Montería have a preference for using free software, often without considering the associated conditions. The lack of technical knowledge and awareness of the benefits of open licenses were identified as the main reasons for

their reluctance to adopt open-source software. Despite these challenges, the implementation of open-source software in SMEs can bring numerous legal and economic advantages, including cost reduction, decreased risk of copyright infringement, and compliance with data protection and privacy laws. In a country like Colombia, where SMEs represent 98% of all companies and contribute to 80% of employment, the adoption of FOSS can be a viable strategy to improve efficiency, productivity, and competitiveness. However, the study also highlights the scarcity of research on the implementation of FOSS in SMEs, not only in Montería but also in Colombia in general, underscoring the need for more studies in this field.

The study carried out has significant implications for academics, policymakers, and legal experts. The findings can be used as a basis for future research on the implementation of FOSS in Colombian SMEs and to advocate for public policies that promote its adoption. It is also pointed out that the shift towards Industry 4.0 can be facilitated through the implementation of FOSS, contributing to the achievement of the sustainable development goals (SDGs). The adoption of FOSS by Colombian SMEs can not only improve competitiveness and innovation but can also serve as a strategy to align their operations with the SDGs. FOSS promotes collaboration and knowledge sharing, thus supporting the achievement of the SDGs that promote the construction of resilient infrastructures, inclusive and sustainable industrialization, and innovation. Additionally, the study suggests that the implementation of FOSS in SMEs can help to reduce the digital divide and promote equitable access to information and communication technologies. Finally, the adoption of open-source software can enable SMEs to address key aspects of Industry 4.0, including the adoption of emerging technologies such as the IoT, machine learning, AI, and big data analysis. This, in turn, can stimulate job creation and foster the development of technical skills within the local economy, contributing to the achievement of the SDG that promotes inclusive and sustainable economic growth and decent work for all.

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