Challenges and Opportunities in the Software Process Improvement in Small and Medium Enterprises: A Field Study

Gledston Carneiro da Silva and Glauco de Figueiredo Carneiro
Salvador University (UNIFACS), Bahia, Brazil

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Abstract: The characteristics and profiles of organizations are important issues for the planning of their software process improvement. It supports the alignment with organizational culture as well as with the consolidation of best practices already implemented. This paper presents the results of a field study to identify the perception of the industry about challenges and opportunities of software process improvement faced by Small and Medium Enterprises. This field study aimed at identifying the profile and perception of a group of software development firms concerning software process improvement. The results indicated a list of challenges and activities faced and performed by the companies toward the software process improvement journey.

1 INTRODUCTION

The term *SME* stands for Small and Medium Enterprises and covers a wide range of definitions and measures, varying from country to country and between the sources reporting SME statistics (Ayyagari et al., 2007). Some of the commonly used criteria to identify these companies are the number of employees, total net assets, sales and investment level. However, the most common definition is based on the number of employees. A large number of sources define an SME to have a cut-off range of 0-250 employees (Ayyagari et al., 2007).

Small and medium enterprises (SMEs) are fundamental for the economy of the majority of countries. In countries such as United States, Brazil, Canada, China and India, companies with this profile have significant representativeness in the economy. For this reason, an effective Software Process Improvement (SPI) should take into account difficulties inherent to this type of organization (Dybå, 2005).

This paper presents the results of a field study focused on SMEs to answer the following research questions: i) *What are the main features, challenges and difficulties faced by SMEs that work in software development towards software process improvement?* and ii) *What are the possibilities to support those organizations to overcome these difficulties and to encourage them to embrace the SPI journey?*

The next sections of this paper are organized as follows. Section 2 presents related works. In Section 3 we briefly present the insights acquired during preliminary research, namely when we conducted a Systematic Literature Review (SLR) to find out evidences in the literature about difficulties faced by SMEs during the SPI journey (Silva and Carneiro, 2016). Section 4 discusses the results of a field study to characterize the profile and perception of a set of Brazilian SMEs to compare them with results presented in the SLR (Silva and Carneiro, 2016). Section 5 presents final remarks.

2 RELATED WORKS

In a pilot search for secondary studies using the strings (Systematic Literature Reviews OR SLR) AND (SPI OR software process improvement) on the repositories Digital Library ACM, IEEE Xplore, Science Direct and Google Scholar, we found five Systematic Literature Reviews (SLR) that are somehow related to our two research questions (Pino et al., 2008)(Lavallée and Robillard, 2012)(Bjørnson and Dingsøyr, 2008)(Unterkalmsteiner et al., 2012)(Sulayman and Mendes, 2011).

Pino and colleagues (Pino et al., 2008) published in 2008 a systematic literature review to identify reports and studies focusing on efforts of SMEs in the software process improvement journey. The main goal of their paper was to analyze approaches of SPI related to these type of organizations. According to the same authors, the following items can influence

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on the success of SPI adoption in SMEs: (a) hire expert advice on software process improvement; (b) acquire financial support to fund the software process improvement; (c) establish cooperation among organizations interested in software process improvement so that they can share resources; (d) perform a gap analysis; (f) establish and institutionalize a communication plan considering all stakeholders; (g) motivate senior management sponsorship and strong commitment of all stakeholders. In this paper, we considered papers published until December 2015 and also difficulties and challenges faced by the companies. Moreover, we compared the obtained results with the ones collected in the field study.

Lavallee and Robillard (Lavallée and Robillard, 2012) published in 2012 a systematic literature review to identify papers that focused on the impact of SPI on developers. Among the positive impacts authors identified the reduction in the number of crises, and increase in team communications and morale, as well as better requirements and documentation. On the other hand, as negative impacts they mention the increased overhead on developers through the need to collect data and compile documentation, an undue focus on technical approaches, and the fact that SPI is oriented toward management and process quality, and not towards developers and product quality. Our work did not consider only the developers perspective, but the perspective of the company as a whole.

In (Unterkalmsteiner et al., 2012), the authors identified and characterized evaluation strategies and measurements used to assess the impact of different SPI initiatives. The systematic literature review conducted by the authors included 148 papers published between 1991 and 2008. Seven distinct evaluation strategies were identified, whereas the most common one, Pre-Post Comparison, was applied in 49% of the inspected papers. Quality was the most measured attribute (62%), followed by Cost (41%) and Schedule (18%). Despite these strategies have also been used to evaulated SPI in SMEs, this SLR did not focused exclusively in these types of companies. Thereby, the authors did not mentioned if these strategies are effective for them. The results of this work corroborate the importance of strategies for the success of software process improvement, and we considered this fact in the analysis of the results of this paper.

According to Google Scholar, among these four systematic reviews, (Bjørnson and Dingsøyr, 2008) had the largest number of citations. It was published in 2008 and reports a systematic literature review of empirical studies of knowledge management in software engineering. Among the selected primary studies, there are three publications (Basri S, 2011)(Baskerville R, 1999)(C.G.v. Wangenheim, 2006) that discuss the use of knowledge management approaches to support software process improvement in SMEs. The focus of selected papers reported in (Bjørnson and Dingsøyr, 2008) is not only on SMEs, however the three studies reveal the importance of these companies in the overall context of SPI (Silva and Carneiro, 2016).

In accordance to the SLR published in 2011 (Sulayman and Mendes, 2011), very few studies (only eight) have specifically focused on SPI for Web companies, despite the large number of existing Web companies worldwide, and the even larger number of Web applications being currently developed. The selected studies did not suggest any customized model or technique to measure the SPI of small and medium Web companies. The measures of success for small and medium Web companies, as per SR results, include development team and client satisfaction, increase in productivity, compliance with standards and overall operational excellence. In addition to the limited number of papers (eight studies), the authors did not addressed difficulties and challenges faced by these companies. In order to be successful in the SPI journey they also need to know beforehand possible pitfalls of such adoption. Moreover, the SLR step of this work was based only on eight papers.

3 INSIGHTS FROM A PREVIOUS SYSTEMATIC LITERATURE REVIEW

This section presents some of the results of a SLR conducted by the authors and published at (Silva and Carneiro, 2016). We aimed to answers the following research question **(RQ)** by conducting a methodological review of existing research: *What are the challenges and difficulties faced by SMEs in the adoption of software process improvement?*

The knowledge of these challenges and difficulties support the SMEs to plan and perform SPI alignment with expectations and organizational culture of these companies.

We conducted the SLR in journals and conferences. We extracted 33 peer-reviewed literature papers published from January 2004 to June 2015 (inclusive). Based on the research question, keywords were extracted and used to search the primary study sources. The search string is presented as follows and used the same strategy cited in (Chen and Babar, 2011): *(challenges OR difficulties) AND (small and medium enterprises OR sme) AND (SPI OR software* *process improvement)*

Potentially Relevant Studies. Results obtained from the automatic search and manual search were included on a single spreadsheet: an overall total of 56 results, namely 54 from the automated search plus 02 from the separate manual search. The studies were sorted by title in order to eliminate redundancies. Studies for which the title, author(s), year and abstract were identical were considered redundant. Forty six papers remained after removing the redundant items.

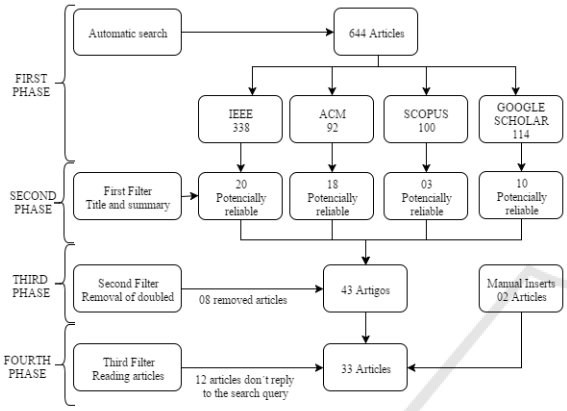

Figure 1: Systematic Literature Review Phases in Numbers (Silva and Carneiro, 2016).

Selection Process. The selection process ended up with 36 papers from which we could obtain evidences to answer the research question. Figure 2 depicts the temporal distribution of the selected studies. As can be observed, more than 97% of the papers were published after 2006, including this year. This is an evidence that the research on software process improvement in small and medium enterprises has been gaining increasing interest from the international software engineering community. At the end, 36 papers were considered relevant to answer the research question **(RQ)**. Table 1 presents an overview of the selection process per public data source (Silva and Carneiro, 2016).

Table 1: Selection Process Overview per Public Data Source (Silva and Carneiro, 2016).

Public Data Source	Search Result	Relevant Studies	Search Effectiveness
IEEE	338	19	5,6%
ACM	92	02	2,1%
SCOPUS	100	03	3%
GOOGLE	114	11	9,6%

We sorted the top ten papers in descending order according to their respective citation number in Google Scholar[1]. The paper M33[2] had the largest number of citations and reports a systematic literature review of empirical studies of knowledge management in software engineering. Among the selected primary studies, there are five publications (M24, M30, M33) that discuss the use of knowledge management approaches to support software process improvement in SMEs. Despite the selected papers of this SLR do not focus only on these types of companies, these studies are evidences of its importance in the overall context of SPI.

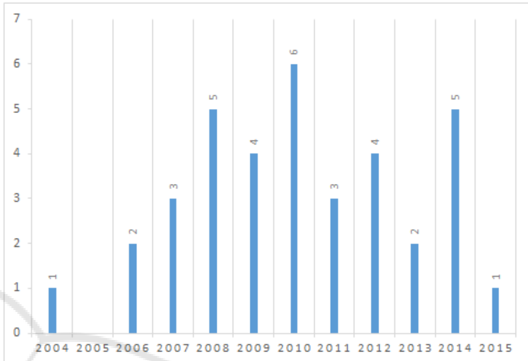

Figure 2: Timeline Distribution of Papers (Silva and Carneiro, 2016).

Characteristics, Challenges and Difficulties faced by SMEs towards SPI Adoption. The selected studies show evidences of peculiarities regarding SMEs, indicating the necessity of specific approaches and solutions for an effective software process improvement adoption. This is especially evident when comparing this scenario with large organizations. Factors related to *financial restrictions and human resource constraints (Challenge 1)* were cited in 24 papers of the 36 of the SLR (M01-M07, M10, M12-M17, M19, M22-M24, M26, M28, M29, M31, M32 and M36), representing 67% of the selected papers (Silva and Carneiro, 2016). It is worth to mention that this does not only refers to direct costs (external consulting and training, for example), but also to indirect costs such as effort required by the team to implement SPI, time required by the teams to understand the SPI rationale and the promote the several required adjustments during the SPI adoption. Due to the financial restrictions, many companies have applied for funding for such end. Typical SMEs project characteristics was the second most cited issue in 14 papers (M01, M03, M04, M07, M11, M12, M14, M15, M17, M19, M20, M27, M28 e M33), i.e. 39% of the selected primary

[1]The list with the top ten papers as well as the selected papers of this SLR are available at http://www.sourceminer.org/slrsme.html.

[2]Also available in the same url indicated above.

studies pointed out this fact. Due to the the ever changing business and customer demands, *projects with short time frame (Challenge 2)* are also a typical characteristic of SMEs, especially for the ones that focus on the evolution of software products of a given domain (Silva and Carneiro, 2016).

The third issue highlighted by the selected studies is *small teams with work overload - (Challenge 3)* (Silva and Carneiro, 2016). This issue was cited by nine papers (M01-M03, M08, M12, M14, M15, M20 and M31), corresponding to 25% of the selected studies. Small teams in SMEs should be taken into account when planning the software process improvement. In this case, participants of the teams can take different roles depending on the demand. There are roles such as quality auditor that can not be assumed by the team members due to conflict of interest. In this case, an external professional can provide an on-demand service for this purpose.

Low focus on process - (Challenge 4) is an evidence provided by eight papers (M01, M03, M08, M12, M14, M15, M19 and M36), corresponding to 22% of the selected papers. It reveals how SMEs deal with daily development practices. This means that organizations can be subjected to conduct software projects in a non-coordinated way and the teams involved in the software projects are not always concerned with software process improvement (Silva and Carneiro, 2016). *Limited number of customers - (Challenge 5)* is another issue pointed out by seven (M01, M03, M06, M07, M12, M15 and M22) (19%) of the selected studies. These type of companies need to maintain the relationship with their clients, otherwise the company can suffer the consequences of the competitors.

Agility to deal with requirements volatility - (Challenge 6) was an issue identified in six papers (M01, M03, M07, M15, M18 and M34) corresponding to 17% of the selected studies. Even after validating the requirements with the client, change in requirements are inevitable. Responding to these demands is crucial to keep clients satisfied. *Absence of training focusing on process - (Challenge 7)* was also identified in six papers (M03, M08, M12, M14, M19 and M35) corresponding to 17% of the selected studies.

Protection of intellectual property - (Challenge 8) also corresponds to 17% of the selected studies (M06, M24, M25, M30, M33 and M35) and has the potentiality to encourage companies and their teams to innovate in new products, new techniques or approaches that can lead to market differential. The next issues are *difficulty to include best practices- (Challenge 9)*, mentioned in five studies (M01, M12, M14, M19 and M36) and *high cost of SPI qualified professionals - Challenge 10* - reported in studies M02, M05, M11, M13 and M34 (Silva and Carneiro, 2016). The results of this SLR were used as reference for the field study presented in the next section.

4 FIELD STUDY IN SMALL AND MEDIUM ENTERPRISES

This sections presents the results of a field study to characterize the perception of Small and Medium Enterprises (SMEs) from Feira de Santana city of State of Bahia in Brazil. The reason for having chosen this city was the perceived number of organizations willing to implement software process improvement practices, despite not having any company officially adopted a well-known software process reference model such as CMMI (Chrissis et al., 2011) or MPS.BR (Montoni et al., 2009). This was considered an appropriate scenario to perform the field study, to collect and analyze data as well as to compare them with the findings obtained in the Systematic Literature Review already conducted by the authors (Silva and Carneiro, 2016) and briefly presented in the previous section.

4.1 Planning and Execution

We contacted 30 companies from Feira de Santana city. Eleven companies agreed to take part in the study. We conducted semi-structured face-to-face interviews with representatives of these companies to collect data for the characterization study. We considered the forms published in (Sulayman et al., 2012) to be adjusted and used in this study[3]. According to the confidentially agreement, the identification of the companies were preserved. The goal of the first form was to collect data related to the interviewed profile representing each company. The second form collected data related to the company. The third form had the goal to evaluate to which extent the company was aligned to the seven items proposed by (Dybå, 2003) and listed as follows: a) *Business orientation*: the extent to which SPI goals and actions are aligned with explicit and implicit business goals and strategies; b) *Involved leadership*: the extent to which leaders at all levels in the organization are genuinely committed to and actively participate in SPI; c) *Employee participation*: the extent to which employees use their

[3]The adjusted forms are available at http://www.sourceminer.org/slrsme.html.

knowledge and experience to decide, act, and take responsibility for SPI; d) *Concern for measurement*: the extent to which the software organization collects and utilizes quality data to guide and assess the effects of SPI activities; e) *Exploitation*: the extent to which the software organization is engaged in the exploitation of existing knowledge; f) *Exploration*: the extent to which the software organization is engaged in the exploration of new knowledge (Dybå, 2003). Finally, the fourth form aimed at identifying what the organization had already implemented in terms of software process improvement.

Profiles of the Participants. Nine of the participants had worked at least three years in the company. On the other hand, four of the interviewed had worked at least five years. Nine of the interviewed were project managers and the other two took were members of the software engineering process group.

Profiles of the Organizations. Five companies had developed software for at least five years, whereas three companies had operated in the market for at least fifteen years, two companies had between five and ten years. Finally, just one company had less than five years. Considering that eight companies had up to five professionals, one company had seven professionals and two companies had more than ten professionals, we can conclude that there is to some extent a relationship with Challenge 1 reported in the previous section - *financial restrictions and human resource constraints* and Challenge 3 - *small teams with work overload*.

All the companies are located in Feira de Santana city in the Bahia State of Brazil. Due to the majority of companies with less than five employees, the Software Quality process activities, including the audits, can be performed by an external professional. This leads to the possibility of sharing this professional among the companies. This is a viable solution to circumvent the challenge of human resources constraints. This number of professionals is an issue that should certainly influence the occurrences of *small teams with work overload - (Challenge 3)*. This overload can impact the participation of professionals in activities related to the SPI such as process elaboration and review as well as training. And participating in these activities compromise the capacity of the company in its ongoing projects. This has as a natural consequence in the increase of natural expenditures.

Regarding the project duration, 55% of the companies reported that their projects end in a maximum of ten weeks. This is a clear evidence of focus on small projects. In fact, even working with software product evolution, these companies tend to split the activities in small chunks. This was identified in (Silva and Carneiro, 2016) as *projects with short time frame (Challenge 2)*. A possible explanation for this scenario is that the majority of these companies evolve software products for a specific domain. Another fact that was identified during the interviews was that these companies suffer the influence of agile methods, especially Scrum. These approaches somehow motivate teams to deal with small projects.

4.2 Success Factors in SPI Initiatives

Table 2 presents data related to the third form of the field study focusing on *Business Orientation*. Data collected from the field study reveal which items from the *Business Orientation* were considered relevant by the companies: 1 - *We have established unambiguous goals for the organizations SPI activities*, was mentioned by 64% of the companies. Companies developed their process based on strategic planning and directed/adjusted efforts of SPI aligned with their needs. Approximately 64% of the companies informed that *our SPI goals are closely aligned with the organizations business goals*. The establishment of goals can have as a consequence a possible push in business as a result of SPI initiatives.

Table 2: Success Factors in the Business Orientation Perspective.

Activity	Practice
1 - We have established unambiguous goals for the organizations SPI activities.	64%
2 - There is a broad understanding of SPI goals and policy within our organization.	28%
3 - Our SPI activities are closely integrated with software development activities.	55%
4 Our SPI goals are closely aligned with the organizations business goals.	64%
5 We have a fine balance between short-term and long-term SPI goals.	09%

Table 3 describes quantitatively how companies perceive success factors from the Leadership Engagement perspective. A percentage of 73% of the companies inform that the staff actively support SPI activities. As a natural consequence, the activity *8 Management considers SPI as a way to increase competitive advantage* is recognized by 64% of the companies to justify investiment in SPI to improve the quality of software products. On the other hand, 73% of the companies agree that activity *9 Management is ac-*

Table 3: Success Factors in the Leadership Engagement Perspective.

Activity	Practice
6 Management is actively supporting SPI activities.	73%
7 Management accepts responsibility for SPI.	55%
8 Management considers SPI as a way to increase competitive advantage.	64%
9 Management is actively participating in SPI activities.	73%
10 SPI issues are often discussed in top management meetings.	45%

tively participating in SPI activities is associated with the initiatives they have seen in their companies.

Table 4 describes quantitatively how companies perceive success factors from the Employee Participation perspective. Activities 11 (*Software developers are involved to a great extent in decisions about the implementation of their own work*) and *12 - Software developers are actively contributing with SPI proposals* were recognized by 73% of the interviewed companies. In that sense, employees recognize that they are encouraged to suggest changes in projects and process in the company. Despite being initially not confident to provide suggestions, later on they contribute with suggestions related to the SPI activities. This is corroborated by the fact that 91% of the interviewed agreed that *13 Software developers are actively involved in creating routines and procedures for software development*.

Table 4: Success Factors (Software Process Improvement) Employee Participation.

Activity	Practice
11 Software developers are involved to a great extent in decisions about the implementation of their own work.	73%
12 Software developers are actively contributing with SPI proposals.	73%
13 Softwaredevelopers are actively involved in creating routines and procedures for software development.	91%
14 We have an ongoing dialogue and discussion about software development.	64%
15 Software developers have responsibility related to the organizations SPI activities.	64%
16 Software developers are actively involved in setting goals for our SPI activities.	64%
17 We have an ongoing dialogue and discussion about. SPI.	64%

Table 5: Success Factors (Software Process Improvement) Concern for Measurement.

Activity	Practice
18 We consider it important to measure organizational performance.	64%
19 We regularly collect quality data (e.g. defects, timeliness) from our projects.	64%
20 Information on quality data is readily available to software developers.	55%
21 Information on quality data is readily available to management.	55%
22 We use quality data as a basis for SPI.	55%
23 Our software projects get regular feedback on their performance.	64%

Table 5 describes quantitatively how companies perceive success factors from the Concern for Measurement perspective. The majority of the companies (64%) recognize the relevance of measuring organizational performance as stated by activity 18 (*We consider it important to measure organizational performance.* Software life-cycle activities need to be measured to evaluate its performance and indicators are required for this end. Another two activities related to the measurement perspective were also classified as relevant by 64% of the companies: *19 - We regularly collect quality data (e.g. defects, timeliness) from our projects* and *23 - Our software projects get regular feedback on their performance*. The companies reported that indicators were planned, collected an later analyzed/compared with their respective targets. However, they also recognized that there is the need to improve the way measurement is performed during software projects life-cycle, especially due to the effort required to accomplish measurement related activities.

Table 6 portrays success factors regarding Exploitation of Existing Knowledge. The following activities were recognized by 73% of the companies 25 *We are systematically learning from the experience of prior projects* and 26 *26 - Our routines for software development are based on experience from prior projects*. Table 7 focuses on success factors regarding Exploitation of New Knowledge. The activities 31 *In our organization, we encourage innovation and creativity*, 34 *We have the ability to question established truths* had both 82% of representation by

Table 6: Success Factors (Software Process Improvement) Exploitation of Existing Knowledge.

Activity	Practice
24 We exploit the existing organizational knowledge to the utmost extent.	45%
25 We are systematically learning from the experience of prior projects.	73%
26 Our routines for software development are based on experience from prior projects.	73%
27 We collect and classify experience from prior projects.	36%
28 We put great emphasis on internal transfer of positive and negative experience.	55%
29 To the extent we can avoid it, we do not take risks by experimenting with new ways of working.	55%

Table 7: Success Factors (Software Process Improvement) Exploitation of New Knowledge.

Activity	Practice
30 We are very capable at managing uncertainty in the organizations environment.	36%
31 In our organization, we encourage innovation and creativity.	82%
32 We often carry out trials with new software engineering methods and tools.	45%
33 We often conduct experiments with new ways of working with software development.	27%
34 We have the ability to question established truths.	82%
35 We are very flexible in the way we carry out our work.	73%
36 We do not specify work processes more than what are absolutely necessary.	28%

the participants. They reported that their companies have encouraged professionals to propose solutions creatively considering the possibility of rewards.

Finally, the activity 35 *We are very flexible in the way we carry out our work* was confirmed by 73% of the participants that commented that flexibility is a key factor to face the challenges during software project development and evolution in the sense that requirements evolve continuously and the software product must meet the expectations of clients.

4.3 Software Process Improvement in Practice

Table 8 presents the results related to process and activities that have actually been implemented in the companies. Table 9 presents the results of the perception of the companies that took part in the field study regarding the relevance of Software Process Improvement for their business.

Table 8: To what extent the SPI processes/activities listed in the table below are performed in your organization for projects?

Activity	Practice
37 Motivation for the use of CMMI and MPS.BR	73%
38 Requirements Engineering	55%
39 Project Management	64%

Table 9: How important do you think are the following SPI processes/activities for projects in your organization?

Activity	Practice
40 Motivation for the use of CMMI and MPS.BR	73%
41 Requirements Engineering	73%
42 Project Management	64%

An important finding reported in Tables 8 and 9 was despite the relatively high motivation reported by the companies to implement well-known reference models such as CMMI (Chrissis et al., 2011) or MPS.BR (Montoni et al., 2009), they have not yet prepared for the evaluation. Among the reasons provided was *financial restrictions and human resource constraints (Challenge 1)* of the SLR presented in Section 3. The companies in fact revealed that they need external sponsorship to implement such models to overcome direct and indirect costs of this initiative. However, despite these constraints, the companies demonstrate motivation (Table 9) for the challenge of SPI, considering both the interviewed professionals and staff, what is a positive fact to achieve effective results in this journey.

Limitations of the Characterization Study. Two possible limitations were identified in this characterization. The first was related to the fact that the profile, number and location of the companies that took part in the study could somehow prevent the generalization of the results. However, it was verified that the profile of the companies in terms of number of professionals, type, duration and number of software projects and gross operational income were compatible with the values provided by several references of Small and Medium Enterprises that work in the area of software development. The second limitation refers to the number of companies in the characterization. They correspond to approximately half of the companies of the region, for that reason, for some extent they represent a reasonable sampling in terms of profile. The fact that the majority of the interviewed professionals (82%) was from staff could had influence the answers. In a new version of the study we will select participants from different roles for a better distribution of profiles. However, despite these limitations, we could confirm some of the results from our systematic literature review such as financial restrictions and human resource constraints, projects with short time frame and small teams with work overload.

5 CONCLUSION

This paper presents a characterization of Small and Medium Enterprises aimed at identifying challenges, difficulties and opportunities in the context of Software Process Improvement (SPI). The characterization consisted in comparing the results obtained from a systematic literature review and from a field study. The results present a list of challenges and activities faced and performed by the companies toward the software process improvement journey. They can be a reference for companies that plan to adopt SPI and researchers that can conduct new studies to compare this scenario with other small and medium enterprises experiences.

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