

Critical Success Factors and Barriers for Lightweight Software Process Improvement in Agile Development

A Literature Review

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Abstract: The majority of software development companies are significantly benefitted by adopting software process improvement (SPI). This has been extensively addressed both in terms of research and established standards. In particular, the need for SPI in the context of Small and Medium-sized Enterprises (SMEs) led a lot of researchers to focus on this area. SMEs struggle daily to survive in a very competitive environment and their distinguishing characteristics such as the small number of employees, the flat and small organizational structure and the flexibility that governs them make it hard for them to adopt and implement SPI. On the same spirit, their distinguishing characteristics are also those that make SMEs an ideal environment for the adoption of agile methodologies. The agility that governs SMEs allows flexibility in every process they apply and, thus, promotes lightweight SPI approaches in order to remain on the battle fields of competition. In this article, we examine the special characteristics SMEs have and highlight critical success factors that should be taken advantage of and barriers that could be avoided during SPI, as they are presented in the relevant literature. In addition, we examine how critical success factors of SPI could positively affect a firm's Return on Investment and, consequently, help the firm survive in the long-term.

1 INTRODUCTION

In an era where the classic saying "Time is money" is more than ever true, thousands of (small and medium-sized) enterprises are struggling daily to improve their processes in order to survive. Although the rapid development of methods and tools has provided a long list of software process improvement (SPI) alternatives for the well-established large enterprises, software Small and Medium Enterprises (SMEs) all around the world are still trying to find tailored solutions to their needs to quickly adapt to changes and, at the same time, maximize Return On Investment (ROI).

During the last decade, a lot of research has been done in the field of implementing SPI in the context of SMEs. Lately, there is a need to focus on small and medium companies using agile development methodologies. More specific, a lot of interest has been shown in companies that adopt lightweight SPI.

Today, we are in a position to identify critical success factors and barriers of lightweight SPI for SMEs implementing agile development processes and focus on the cost these factors bring in SMEs.

In particular, this paper aims to answer the following research questions:

- RQ1: What are the special characteristics of software SMEs that follow agile methodologies?
- RQ2: What are the main Critical Success Factors and Barriers involved in SPI?
- RQ3: How do the Critical Success Factors and Barriers affect the ROI in companies that apply lightweight SPI?

The answer of these questions will be helpful to identify the significance of these factors for a successful SPI implementation and will potentially support SMEs that follow agile methodologies to concentrate on satisfying them in order to achieve higher ROI in a shorter amount of time.

The rest of the paper is structured as follows: Section 2 provides information on related studies and previous work on similar topics. Section 3 highlights the special characteristics of agile organizations and summarizes the benefits and limitations known for SMEs that apply such methodologies. Section 4 identifies a list of critical success factors and barriers as presented in the literature that firms have to address when considering to implement SPI. Section 5 specifies a group of success factors and barriers that relate with ROI resulting from adopting a lightweight SPI in the context of a company realizing agile development. Finally, section 6 provides the conclusions and future work as they emerge from this study and identifies some research gaps in the related area.

2 RELATED WORK

An extensive amount of papers deals with SPI as it is vital for software organizations to successfully re-engineer their processes and find a cost effective solution to deliver software products and services. However, to the best of our knowledge, there is no review article that specifically concentrates on critical success factors and barriers in the context of lightweight SPI in software SMEs following agile development practices.

In (Viju et al., 2013) the authors present a comparative analysis of the problems SMEs face in adopting SPI. Among others, in this paper the negative perception of SMEs about various standards and methods such as SPI-KM, RAPID, MR-MPS and CMMI, the difficulties in relating SPI with benefits and the availability and shared ability of successful SPI best practices are presented. The authors conclude at the end of the paper that at the time there was insufficient knowledge about which innovations were effective and which factors influenced the adoption of SPI in SMEs and on the fact that there is a need to develop a software process model based on the features required by SMEs on SPI models.

In (Villalon et al., 2002) the difficulty to apply SPI in SMEs is assigned to various cost types (financial, time, resources) and is suggested that organizations that are initiating SPI efforts should first assess their current capability to develop and maintain software products. Assessment helps to identify the strengths and weaknesses of the process evaluated with respect to a software process model, e.g. CMMI. At the end, the process to be improved is selected. This paper presents a new SPI method called MESOPYME whose main focus is to reduce effort and time on the

SPI implementation. This specific method focuses on the improvement implementation stage based on the concept of Action Package that is a set of components which help to give a concrete solution to a software development problem. The authors conclude that the Action Package can be used in various improvement methods providing a working guide to begin improvement implementation and, therefore, to achieve reduction in effort, time and cost.

In (Cater-Steel et al., 2006) an assessment model based on ISO/IEC 15504 is applied prior to SPI in small firms. Low-rigor, one-day SPI assessments were offered for free to 22 small Australian software development firms. After one year the firms had a follow-up meeting to determine the extent to which they had implemented the recommendations derived from the assessments. The analysis of the assessment and follow-up report highlighted important issues for SPI such as: elapsed time from assessment to follow-up meeting, need for mentoring, and readiness of firms for SPI etc. Finally, the authors advice small firms not to undertake SPI if their operation is likely to be disrupted by events in the internal or external environment of the firm.

A more recent research work (O'Connor and Laporte, 2011) supports that top-down SPI standards like CMMI (Capability Maturity Model Integration) and ISO 9000 that were developed to assist companies in performing SPI, are not being widely adopted and their influence in the software industry remains more at a theoretical than practical level. This is again mainly due to the cost that is associated with SPI. Especially for SMEs, they find it difficult to relate these standards to their business needs and the vast majority of these cannot afford the resources for establishing software processes as defined by current standards and maturity models such as CMMI, ISO 9000 and SPICE.

Key challenges in process improvement for small businesses like the understanding of the assessed processes, identification of their strengths and weaknesses and the importance of staff commitment are highlighted in (Anacleto et al., 2004). The authors applied a customized assessment method based on ISO/IEC 15504 standard and focused on process improvement in four small software companies in Brazil. Assessments were found to be very beneficial as they led to better understanding of the assessed processes, helped on the identification of strengths and weaknesses of the assessed processes, showed ways to improve the software process and increased the commitment of employees involved in SPI.

A systematic literature review was presented in (Pino et al., 2008) that deals with existing approaches

of SPI in SMEs. Here, the authors discussed the significant issues related to this area like the approaches that SMEs follow on SPI, the number of employees committed on SPI and the factors that affect the end results of an SPI effort. The review focused primarily on case studies carried out in industry. Following the guidelines of Kitchenham (Kitchenham, 2004) and the protocol template of Biolchini et al., (2005), they searched in five digital libraries of research articles and identified 45 primary relevant studies. From the statistical analysis on the selected studies they identified that company commitment is vital for SPI success in a company. They concluded that existing models such as CMMI can be applied only with difficulty in SMEs and so there is an increased need of alternate models and approaches for firms of this size.

Finally, (Clarke and O'Connor, 2012) also discusses SPI and positively associates SPI with business success using the Holistic Scorecard (HC) (Sureshchandar and Leisten, 2005) as a business success reference framework with the aim to examine both the financial and non-financial aspects of business success. HC was developed as a business success measurement framework for software development organizations and is composed of 6 classifications of business objectives and a listing of 16 critical success factors associated with the 6 business objectives. The authors found a positive association between SPI and business success in software SMEs and this finding highlights the importance of SPI in successful software SMEs.

The current paper emphasizes on lightweight approaches to realize SPI particularly suitable for SMEs. A lightweight approach requires less time and effort and consequently less cost for SPI implementation. Cost is managed ad hoc as there is no standard procedure for SPI in a lightweight case. A firm can follow a bottom up procedure to improve its business processes as it can first identify the most critical problems and then work towards the solution of them. A lightweight approach provides the ability to improve specific process areas that will improve the overall performance of a company.

3 AGILE SW DEVELOPMENT

Although there is not a typical definition for Agile Software Development, the vast majority of researchers and practitioners in the field agree on a single value: there is always the need to deliver faster, better and cheaper solutions to customers. This created the need for software development methods

that would be able to directly respond to customer's changing needs and quickly provide a product that would satisfy those needs before competitors catch.

According to (Pino et al., 2010) small organizations share some specific characteristics:

- They follow lightweight processes which focus in person-to-person communication: this enables communication and sharing of information among every person in the company.
- They are flexible: Flexibility is useful in a world where user requirements change on a daily basis. However, in a strict SPI procedure where following well-documented guidelines is considered a critical success factor, flexibility may not always work in favour of the development team.
- They follow informal mechanisms to manage every day activities: Communication, decision making and problem resolution are then facilitated.
- Their staff is not expertized in several specialized functions of the firm: This might prove to be fatal in some cases of SPI as staff experience is very important for the successful application of SPI.
- Their economic resources are limited: SPI is often an expensive procedure that normally yields profits after a significant amount of time has passed. In small firms this alone might be a major reason to not involve with SPI initiatives.

These characteristics indicate that appropriate management for SPI processes is required for companies that go agile. Agile methods are usually adapted in SMEs. This happens because agile practices can best be applied in their software processes basically due to the small initial investment required. On the other hand, the agility of SMEs can speed up SPI (Viju et al., 2013). An agile team is flexible enough to continue evaluating company's needs even throughout the SPI process. This guarantees that an improvement initiative is always emphasizing on the most valuable processes providing eventually more profits for the organization.

4 CRITICAL SUCCESS FACTORS AND BARRIERS

As presented in section 2, the successful implementation of SPI is crucial for every organization as it requires not only a lot of time but an extensive amount of other resources as well. In the last decade, a lot of research has been done in the

critical success factors and barriers that are associated with the decision an organization takes to perform SPI. In the remaining of this section a detailed list is provided with the most common critical success factors and barriers as those are reported in the literature. A general discussion for the most popular of these is provided in order for the reader to understand the point to which each factor/barrier affects the decision of a firm for adopting SPI.

4.1 Commitment

Senior management commitment (Cater-Steel, 2004; Cater-Steel et al., 2006; Dybå and Dingsøy, 2008; Ferreira et al., 2007; McCaffery et al., 2007; Niazi, 2006; Niazi and Babar, 2009; Niazi et al., 2005a; Niazi et al., 2005b; Niazi et al., 2006; Pino et al., 2008; Viju et al., 2013; von Wangenheim et al., 2006) appears to be a vital success factor in the implementation of SPI in an organization. This is mainly due to the fact that higher management involvement in the procedure guarantees the achievement of good results. Since the top employees in the hierarchy work close enough with other employees to ensure that the selected process attains the agreed standards this serves as a security mechanism that provides quality results at the end. In addition, high involvement from the part of management ensures that every step of the process is tailored to the business goals and provides control on the allocation of all resources making sure these are spent in the most efficient manner.

4.2 Staff Involvement

Staff involvement (Cater-Steel, 2004; Dybå and Dingsøy, 2008; Ferreira et al., 2007; McCaffery et al., 2007; Niazi et al., 2005a; Niazi et al., 2005b; Niazi et al., 2006; Pino et al., 2008; Pino et al., 2010; von Wangenheim et al., 2006) is presented in the literature as a success factor of great importance. Since the procedures for SPI are applied in the internal environment of an organization this means that the higher the involvement of the employees the higher the productivity will be. Especially in a firm that chooses agile development, where communication and agility are important practices, the actions of the staff will directly affect the success of the whole procedure. In SMEs, where the number of employees is significantly smaller than that of a big organization, the role of the employees is even more important as they have to work for the establishment of standards in an organization that will eventually provide them with career opportunities.

4.3 Training

Organizations have nowadays realized that experienced staff and training (Cater-Steel et al., 2006; Ferreira et al., 2007; Niazi et al., 2005b; Niazi et al., 2006; Pino et al., 2008; Viju et al., 2013) are an integral part of SPI implementation (Niazi et al., 2006). As a result, by providing training sessions and knowledge to the employees, management familiarizes the staff with SPI procedures and benefits and as a result they successfully achieve together the desired results. However, the lack of training cannot only withhold the commitment of the employees but can also delay the attainment of ROI for the organization.

4.4 Resources

On the one hand, staff time is directly associated to the previously mentioned success factor “staff involvement”. On the other hand, the time spent by the staff is also related to the resources (Cater-Steel, 2004; Ferreira et al., 2007; Niazi, 2006; Niazi and Babar, 2009; Niazi et al., 2005a; Niazi et al., 2005b; Niazi et al., 2006; Pino et al., 2010; Unterkalmsteiner et al., 2012; Villalon et al., 2002; Viju et al., 2013; von Wangenheim et al., 2006) available by the organization. Either these are money, or time, or number of employees or even the technological equipment of the company it is clear that an SPI activity will eventually be tailored according to the available resources. Limited resources can either cause the activity to be partially executed, causing misleading results or the whole activity to be applied in a very short amount of time by omitting vital stages. Both situations will not guarantee the improvement of the processes in an organization and thus, cannot also guarantee a higher ROI in the long term. In contrast, the availability of adequate resources will provide the proper environment for the SPI procedure to be carried out following all improvement guidelines and performing the required assessment of current processes leading to more accurate results that will add eventually more value to the organization.

4.5 Process Action Teams

In agile software development the members of the development team work closely together and thus have enhanced communication. A manager can easily recognize the advantages and fields of expertise of each one person in the team and can make appropriate selections and form process action teams (Ferreira et

al., 2007; McCaffery et al., 2007; Niazi et al., 2005a; Niazi et al., 2005b; Niazi et al., 2006) that will work on specific tasks for SPI. By having the right people, on the right teams, working on the right tasks can improve both the process of SPI and the results achieved as well. However, the formulation of the teams must be based on appropriate criteria that can be different for every task of the SPI process.

4.6 Staff Experience

The more experienced (Cater-Steel, 2004; Ferreira et al., 2007; McCaffery et al., 2007; Niazi et al., 2005a; Niazi et al., 2005b; Niazi et al., 2006; Viju et al., 2013) the employees in the organization, the better for the SPI process. This is due to the fact that experienced staff is familiar with the way the organization performs on a daily basis and so they are in position to indicate where problems arise and what good practices are currently applied. Experienced staff can provide the knowledge required to the team leading the SPI initiative for the organization so that they then proceed to the analysis targeted to the needs of the company. Inexperienced staff cannot only make the procedure last longer or seem more complicated but also put at risk the accomplishment of tasks.

4.7 Guidance

Since small organizations that follow agile practices find it generally difficult to adopt pre-existing standards of SPI, the guidance (Cater-Steel et al., 2006; Dybå and Dingsøy, 2008; Niazi et al., 2005a; Niazi et al., 2005b; Niazi et al., 2006; Pino et al., 2010; Villalon et al., 2002; von Wangenheim et al., 2006) that they receive on their approach for process improvement is very important. In particular, in the articles mentioned above, it is clearly stated that companies who follow a sequence of activities for improvement that is tailored to their own business processes generally enjoy more benefits at the end. This happens because the presence of an engineer who will guide the management and staff during this time-consuming and costly procedure unofficially guarantees that the targets set at the beginning will be met and that the plan established by considering the resources invested will also be applied.

4.8 Reviews - Feedback

In organizations that follow agile methodologies communication is very important. The reviews (Dybå and Dingsøy, 2008; Niazi et al., 2005a; Niazi et al.,

2005b; Niazi et al., 2006; von Wangenheim et al., 2006) that occur after the analysis of the existing processes that contain all the problems and good practices that the organization currently follows are a way to communicating to the staff areas that need improvement. The feedback that is also providing during the SPI process and the software process assessment performed in the meanwhile, has been proved vital to the establishment of good practices after the procedure is finalized.

4.9 Implementation Methodology

This is another important success factor related with guidance. A defined SPI implementation methodology (Dybå and Dingsøy, 2008; Ferreira et al., 2007; Niazi, 2006; Niazi and Babar, 2009; Niazi et al., 2005a; Niazi et al., 2006; Pino et al., 2008; Viju et al., 2013) guarantees that analysis has been performed prior to the beginning of this process. During the analysis all the problems of the organization were examined and all the available resources were also taken into consideration. This means that since there are some steps to guide the team through the SPI process there is less probability the outcomes will be poor and more chances on higher ROI and more effective processes. At the end, it is the managers that need the guidance on how to implement the SPI activities and the defined implementation methodology plays a vital role in the implementation of SPI programs.

4.10 Monitoring

In the critical success factors that are being analyzed, it is clear that the vast majority of factors is related to guidance in SPI. In this domain, there are several variations in order to cover every aspect of this complicated procedure for an organization. Monitoring and supervision (Dybå and Dingsøy, 2008; Niazi and Babar, 2009; Niazi et al., 2006; Pino et al., 2008; Pino et al., 2010) are very important even though a defined SPI implementation methodology might be already taking place in a firm. It shows that even though all proper analysis has been performed and the steps have already been discovered, there is also a need to ensure that they are being followed. Monitoring establishes that the procedure decided is applied and also ensures that there are no deviations from the agreed resource allocation plan.

4.11 Communication

Senior executives, department managers, employees

and SPI engineers are all involved in the complicated and time consuming process for improving the processes in the organization. Since the commitment of each one of the teams stated above is very important for the completion of the process, it is valuable to ensure that all of these teams can communicate. Communication (Niazi et al., 2005a; Niazi et al., 2006; Pino et al., 2008; Pino et al., 2010) might involve daily meetings and exchange of opinions but can also involve various checks performed to ensure that the process is being applied as agreed.

4.12 Return on Investment

Although attainment of high ROI (Niazi and Babar, 2009; Pino et al., 2008; Pino et al., 2010) was explicitly declared in 3 articles in the literature, it is of great importance if not of the greatest. At the end of the day, every organization proceeds in SPI in order to improve daily activities and achieve great operational excellence. SPI is such a consuming process that requires not only extensive allocation of resources but great effort from all the participants that eventually the only thing that makes it worth it is the attainment of high ROI that will benefit the organization on the long term. In section 5 of the paper the relationship of ROI with lightweight SPI is further discussed.

4.13 Awareness of SPI

Awareness of SPI (Ferreira et al., 2007; Niazi, 2006; Niazi and Babar, 2009; Niazi et al., 2005a; Niazi et al., 2005b; Niazi et al., 2006) is one of the first steps towards the success of SPI. When all the parties involved in the process understand the high benefits this provides upon completion and all the parties are aware of the problems that arise if such an expensive process is not carried out appropriately, then this is the key to a good start. The knowledge that emerges from being aware of the benefits and risks of SPI is valuable because it can be used to shed some lights on aspects of the current process that could be candidate for improvement. In addition, being updated on all the new practices and tools that can be used during the new established processes can also help as technology drastically changes on a daily basis and techniques that were not available yesterday might arise today. The adaption of such techniques can facilitate an organization to adjust the costs according to its resources and even help achieve fastest ROI.

4.14 Additional Critical Success Factors and Barriers

Other critical success factors and barriers that do not appear in the literature very often are the following:

Critical Success Factors

- Flexibility of SPI model (Pino et al., 2008; von Wangenheim et al., 2006)
- Identification of risks and improvement opportunities (von Wangenheim et al., 2006)
- Assignment and responsibility of SPI (Niazi et al., 2005a)
- Overcome resistance (Ferreira et al., 2007)
- High management feeling of ROI (Niazi and Babar, 2009)
- Adaptation to volatile requirements (Niazi and Babar, 2009)
- Effective project planning (Niazi and Babar, 2009)
- Minimize resistance to change (Pino et al., 2008)
- Readiness of firms for SPI (Cater-Steel et al., 2006)

Barriers

- Existence of Organizational Politics (Cater-Steel et al., 2006; Ferreira et al., 2007; Niazi et al., 2005a; Niazi et al., 2005b)
- Lack of support (Niazi et al., 2005a; Niazi et al., 2005b; Viju et al., 2013)
- Negative/bad experiences (Niazi, 2006; Niazi and Babar, 2009; Niazi et al., 2005a)
- Paperwork required (Cater-Steel, 2004; Niazi et al., 2005a; Viju et al., 2013)
- Inappropriate and non-existent tools (Cater-Steel et al., 2006; Ferreira et al., 2007; Viju et al., 2013)
- High training costs (Cater-Steel, 2004; Viju et al., 2013)
- ROI produced in medium high time (Niazi and Babar, 2009; Villalon et al., 2002)
- Poor project management activities (Niazi and Babar, 2009)

5 ROI IN RELATION WITH LIGHTWEIGHT SPI IN AGILE DEVELOPMENT

ROI is mainly concerned with the profits that are generated after an amount of resources is invested in an organization. Estimating and planning a large development project is a complex process that

involves the allocation of extensive resources of a company (Torrecilla-Salinas et al., 2015).

As described in the above sections, SPI is a very complicated process. ROI is produced in medium-high time in SPI in general and so for SMEs this is critical as their financial and human resources are limited (Villalon et al., 2002). The more resources are allocated, the more expensive the SPI initiative for a company. And the more resources spent during SPI, the more crucial is the successful implementation of SPI.

Unfortunately, the established models for SPI are tailored mostly for large organizations as they involve strict procedures to guide the process and this makes it difficult for smaller companies to adapt them due to their distinguishing characteristics (Niazi, 2006). An SPI project may require a lot of funds, expertise and management time and so SMEs need to focus on the principal high-priority processes in relation with the company's business goals (von Wangenheim et al., 2006).

In the literature there are some papers that report some metrics for evaluating an SPI initiative. Some success indicators for process improvement are: estimation accuracy, cost, time to market and ROI (Unterkalmsteiner et al., 2012). The aforementioned factors all include cost and thus the allocation of resources is assigned a significant role in order to achieve high revenue in a short time period. If the costs of implementing SPI are viewed as an investment then the payoff is expressed in a temporarily-shifted ROI model (Ferreira et al., 2007).

As presented in (Van Solingen, 2004), analyzing SPI's ROI is relevant for:

- convincing managers to invest money and effort in improvement
- deciding the process to improve first
- carrying out the entire SPI process in the long-term
- surviving.

ROI estimation in agile development is different from that of traditional development. Since agile development allows flexibility and adaptation as the process is being carried out, requirements can change and, as a result, the amount of resources that need to be allocated is also modified. The majority of agile methodologies propose a set of techniques to estimate and plan a project (Torrecilla-Salinas et al., 2015). According to the proposed techniques for cost estimation, managers and engineers are able to identify the most important customer needs that will eventually provide more value to the product. In addition, agile methods presented advanced economic models such as real options (Amram and

Kulatilaka, 1998) that require further examination of every aspect in the development process.

6 CONCLUSIONS

The special characteristics of SMEs require appropriate management for SPI processes. SMEs are great for applying agile methods. Flexibility and communication are inherent parts of agile methodologies and they are both in alignment with a lightweight SPI approach. Lightweight SPI enables SMEs to involve their employees in the execution of the improvement activities and supports them to adopt improvement opportunities in their daily activities.

Lightweight SPI is not alone enough to guarantee success in SMEs. Numerous studies have investigated critical success factors and barriers that directly affect the SPI initiative in a firm (Ferreira et al., 2007; Niazi et al., 2005a; Niazi et al., 2005b). It is obvious that the majority of the Critical Success Factors and the Barriers of the SPI procedure can be related to SMEs using agile methodologies. Considering the critical success factors and the barriers that are involved in an SPI procedure, firms can work towards an approach that will highlight those key process areas in the organization that need to be improved in order to provide more value and eventually higher ROI and profitability.

To conclude, in this paper the detailed examination of studies found in the literature helped extract the most critical success factors and the barriers that are involved in the software process improvement process in a company. Most of the factors are directly related to cost and return on investment and thus it is crucial that they are addressed in order to ensure that the SPI process will benefit the company. SMEs usually follow agile methodologies and are more flexible in the SPI process they follow. That does not mean that they can start changing processes and models without analyzing business processes and estimating the cost. Since their resources are usually limited, they will have to address a lot of issues in order to carry out successfully such a complex process. By focusing on the critical success factors and paying attention to possible barriers that can appear during the process, they can be more confident that eventually all resources spent will be return in the form of high ROI and even the attainment of a competitive advantage.

Currently, we are working on a systematic mapping study that will allow us to further support our findings as it will take in mind all recent related

works on this field. In addition, the study will be empirically supported as it will involve a survey analysis in SMEs investigating the critical success factors and barriers during SPI. We also believe that further analysis of SPI cost is required so that every firm can identify prior to the implementation of an SPI process the cost and effect that will bring in the survival of the firm.

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