Factors Leading to the Success and Sustainability of Software Process Improvement Efforts

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Abstract—**Although software process improvement (SPI) may bring immediate positive results, this does not imply that the results will sustain in the long run. In order to succeed with continuous process improvement and sustain its results, organizations need to be aware of what makes their SPI efforts successful or unsuccessful. This paper presents thirty three factors that primarily contribute to the success and sustainability of SPI efforts. The factors are organized into three categories: (1) organizational factors related to the organizational structure, politics and culture, (2) implementation factors related to the planning, preparation, execution and management of the SPI projects and (3) social factors dealing with human behavior and reactions in the SPI context.**

Keywords- SPI; success factors; sustainability factors; attributes; SPI status; lasting results

I. INTRODUCTION

Many software companies today invest time and resources in Software Process Improvements (SPI) in hope of increasing the effectiveness of their software processes. Despite this, not much evidence has been provided on the sustainability of the SPI results and gains [1]. Most of the reports published so far mainly give an account of the short-term gains instead. Furthermore, few authors have stated that the money and effort invested in SPI do not always lead to successful and long-lasting SPI results [2].

Even if SPI efforts show immediate gains, it is not a guarantee that the gains will be long lasting and sustainable [3]. Processes undergoing improvement may demonstrate temporary gains as a result of initial organizational enthusiasm, eagerness and/or desire to do SPI. These gains, however, may not survive in the long run. The organizations may quickly reverse to the previous software process (pre-SPI), and thereby, make the SPI efforts a waste of time and resources. The reasons for failing with SPI might be many, such as, for instance, lack of long-term management support, weakening provision of SPI resources, ill-alignment of SPI with the business goal.

To succeed with long-term SPI, organizations should continuously plan, monitor and control their SPI efforts and progress. They should continuously identify the reasons contributing to the decay or success of SPI and take appropriate measures. In this way, they will become more conscious of their SPI efforts and their opportunities and limitations which, in turn, will make them more aware of the factors contributing to the long-term success or failure of SPI.

Even though research on SPI is not new and a large number of studies have been dedicated to process improvement, there is no combined expertise on what factors contribute to the long-term SPI success. A large number of empirical and theoretical studies list factors contributing to SPI success [2], [4-17]. None of them, however, focus on the long-term sustainability of the SPI efforts. In addition, some factors contributing to success and sustainability of SPI effort can be extracted from the case studies on SPI implementation [3], [18-30]. The studies either suggest different ways of improving processes, or they report on their experiences and lessons learnt or they discuss the incorporation of the process improvement activities into software development processes. To the authors' best knowledge, there is no study providing an exhaustive list of factors aiding software organizations in sustaining their SPI results.

In this paper, we elicit thirty three factors that primarily contribute to the success and sustainability of SPI efforts. Our goal is to create a basis for identifying factors that contribute to successful and sustainable SPI which, in turn, will aid software companies in defining, planning, monitoring and improving their SPI efforts, and in sustaining their results. This paper is an enhanced version of the previous study of the SPI sustainability success factors that have been published in [1].

The remainder of this paper is organized as follows. Section II presents background of the field. Section III describes the method used during this study. Section IV lists and provides descriptions of thirty three SPI sustainability success factors. Finally, Section V discusses the results of this study, presents final remarks and suggests future work.

II. BACKGROUND

In this section, we provide background about current software process improvement models. Section II.A describes general and common stages of software process improvement process. Section II.B presents process capability and maturity assessment models to be used in SPI. Section II.C presents software process improvement approaches existing today. Finally, Section II.D lists software development methods that incorporate the practices of process improvement.

A. Software Process Improvement

Software process improvement is a set of SPI activities leading to an improved software process quality, and thereby, to an improved software product quality [31]. Each SPI effort is unique in its design. It strongly differs with respect to the individual and cultural characteristics and needs of an organization and the status of the processes undergoing improvement [32], [33]. For this reason, it may be difficult to suggest a process model that is suitable for all kinds of SPI contexts.

Many researchers have proposed high level SPI models, such as [31], [34-36]. These models differ in their designs. Nevertheless, they have defined common cyclic stages that are believed to bring maximum benefit to the improving process and business. The most accepted representation of the continuous SPI is illustrated in Figure 1. Its cyclic phases are:

- *Plan (SPI planning):* aiming at defining process improvement goals and vision, as well as identifying process improvement activities and creating a process change plan.
- *Do (Process change):* aiming at changing the process according to the planned improvement.
- *Check (Process review):* aiming at assessing/ reassessing/measuring the process according to the goals of the process improvement, analyzing the process and its measurements and comparing them to the expected results.
- *Act/Adjust (Process adjustment):* aiming at requesting the corrective actions in order to reach planned results and determining the weaknesses and potential improvements of the SPI process.

B. Process Capability and Maturity Assessment Models

There is a large amount of process maturity models that have been designed to help software organizations to assess the status of their software processes and identify the areas of future improvement. The best known ones are CMM (Capability Maturity Model) [37], CMMI (Capability Maturity Model Integration) [38] and SPICE (Software Process Improvement and Capability dEtermination) [39].

Both CMM and its improved version CMM Integration (CMMI) is a standardized framework for process assessment and improvement [37] [38]. Both models provide software organizations with a roadmap for process standardization and improvement. Their frameworks are based on the implementation of the key practices within certain key process areas according to the set improvements goals and the desired maturity level. CMM and CMMI define five maturity levels for process assessment. The maturity levels of CMMI are: *Initial, Managed, Defined, Qualitatively Managed* and *Optimizing* [38]. CMM has a *staged* representation implying that the improvements are targeted to increase the company's overall capability/maturity level. CMMI, on the other hand, in addition to the *staged* representation also includes the *continuous* representation implying that improvements are focused on companies' specific target process areas. With this structure, CMMI aims to help software organizations to assess their organizational maturity or process area capability, establish priorities for improvement, and implement these improvements [38].

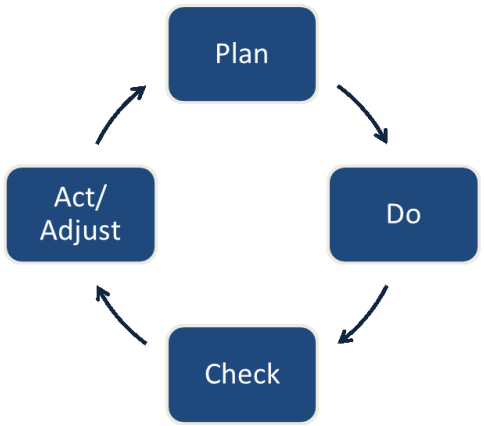

Figure 1. Continuous Software Process Improvement Cycle

SPICE, also known as ISO 15504, is an international reference model for process assessment and improvement. The model can be used for process assessment and its capability determination. In the similar way as CMMI, SPICE is organized into six capability levels that characterize the process as: *Incomplete, Performed, Managed, Established, Predictable* and *Optimizing*. The capability levels, in turn, consist of process attributes, which further consist of generic practices. SPICE model provides tools for standardized process assessment and suggestions for defining process maturity. [39]

C. Software Process Improvement Approaches

Other process improvement approaches or methods can be used as an addition to or as an alternative for capability maturity models. The most commonly used SPI approaches are SixSigma [40] and IDEAL [41].

SixSigma is business management approach for improving engineering and development processes. It is a disciplined data driven approach aiming at improving a development process by identifying and removing the causes of product defects. Using a measurement-based strategy, SixSigma defines how the process is performing and how it should be improved. The improvement of the existing process is done by following five iterative steps: 1) define the defects and project goals, 2) measure the process attributes with respect to its quality and efficiency, 3) analyze the process and determine the root causes of defects, 4) improve the process by eliminating the defined defects, and 5) implement control mechanisms for sustaining the achieved improvements. [40] [42]

IDEAL is a process improvement implementation model that has been primarily designed for supporting the implementation of CMM and CMMI maturity models [43]. It encompasses five stages of a process improvement cycle. Those are the following: 1) *Initialize*: start the improvement program, 2) *Diagnose*: assess the current state of the process, 3) *Establish*: set the implementation strategy and improvement program, 4) *Act*: implement process improvements, 5) *Leverage*: analyze the improvement effort and revise the approach. [34] [41]

D. Software Development Methods that Contain SPI Practices

Many of the software development methods incorporate process improvement activities into their development activities. The best known ones are Lean and Scrum.

Lean software development guides organizations on how to deliver increments of real business value in short time boxes, by means of optimizing/improving their software processes [44]. In the core of Lean software development, there are seven principles aiming at continuous improvement of the process based on the identification and elimination of the inefficiencies (waste) in the process [45]. The core principles are the following: 1) eliminate waste, 2) amplify learning, 3) decide as late as

possible, 4) deliver as fast as possible, 5) empower team, 6) build in product quality, and 7) see the whole [45].

Scrum is a well-known iterative, incremental, light-weight and agile method for software project management. It is most often used in small or medium-sized development organizations. The method is focused on managing software development projects by means of strictly defined: 1) roles, such as scrum master, product owner and the team, 2) meetings, such as daily standups, release and sprint planning meetings, retrospectives and demos, and 3) process artifacts, such as product and sprint backlog [46]. Scrum incorporates in itself continuous process reviews that are done at the end of each development iteration, called *sprint*. This contributes to the light weighted continuous process improvement [32].

III. METHOD

In this section, we present our research method. We first present the research steps in Section III.A. We then describe the questionnaire used in one of the research steps in Section III.B. Finally, in Section III.C, we describe the validity of our results.

A. Research Steps

The overall research consisted of the three following steps: (1) *Literature Study*, (2) *Empirical Study*, and (3) *Data Analysis*.

During the first two steps, we elicited SPI sustainability success factors, first by reviewing literature and then by interviewing software practitioners. These two steps were conducted independently. This implies that the results of the first step did not constitute input to the second step, and vice versa. In the third step, we combined and analyzed the results as achieved in the first two independently done steps. Below, we briefly describe the three steps.

1) Literature Study

During the literature study, we reviewed more than 45 publications dealing with SPI projects. These were mainly experience reports and case studies that had been retrieved from IEEE, ACM, Springer, John Wiley and Sons, and other publishers. Out of them, we chose 27 empirical reports describing conditions contributing to or subtracting from the success of SPI projects [2-27], [30]. Our goal was to draw out factors that contributed to the sustainability of SPI efforts.

The majority of the publications studied mainly reported on the empirical process improvement projects. They did not focus on outlining the conditions contributing to the success of SPI efforts. However, some of the conditions could be indirectly recognized out of their contexts and results. Only three publications provided direct and explicit feedback on critical SPI success factors. These were [4-6].

Based on the literature studied, we drew out factors that were critical for a successful initiation and implementation of SPI, and successful preservation of its results. This step resulted in a preliminary list of SPI sustainability success factors. Having this list as a basis, we reviewed the publications anew, now with the purpose of studying their explicit and implicit descriptions of the success factors, their contexts, and impact on the sustainability of the SPI efforts. This step resulted in twenty seven SPI success factors.

TABLE I. INTERVIEW QUESTIONNAIRE

1. Are you aware that the information you provide will be kept confidential?
2. Have you been involved in process improvement or process transition before? To what extent?
   a. If yes, have the results of the process improvement been lasting?
      i. If yes, why do you think the results have been lasting?
      ii. If no, why do you think the results have not been lasting?
3. What factors contribute to the process improvement sustainability? Please list them and motivate your answers.
4. What factors prevent the process improvement sustainability? Please list them and motivate your answers.
5. What are your suggestions for keeping the process improvement results lasting/sustainable? Please list them and motivate your answers.

2) Empirical Study

During the empirical study, we interviewed 45 software engineers who had been involved in or who had been affected by SPI projects. Among the interviewees, there were twenty seven software developers, ten testers, seven development managers and one SPI manager. They came from twelve different medium-sized software organizations, located in Sweden (23 participants), Vietnam (18 participants), Bangladesh (2 participants), China (1 participant) and Island (1 participant).

Each interviewee was interviewed only once, in a tête à tête manner. Twenty seven interviews were recorded and then transcribed. The other eighteen interviews were not recorded due to the fact that the interviewees felt ill at ease to be recorded. However, the interviews with them were thoroughly documented during and after each interview. On average, the individual interviews lasted for forty minutes.

All the interviews were analyzed using the hermeneutics approach [47]. The SPI success factors listed by the interviewees were analyzed and grouped together when concerning the same or similar issues. The factors that were mentioned by more than one interviewee were joined together and given a common name. The factors that were mentioned by only one interviewee were not included in this paper at all.

3) Data Analysis

During the *Data Analysis* step, we analyzed the results of the literature study and the empirical data using the hermeneutics approach [47]. Here, we identified and analyzed the sustainability factors as drawn out in the former study steps (the literature and empirical study steps). In total, we identified thirty three SPI sustainability success factors, out of which twenty four factors were commonly identified in both literature and empirical studies. Out of twenty seven success factors identified in the literature, three were not confirmed during the empirical study. In addition, six out of the thirty factors identified during the empirical study had not been identified in the literature studied.

Finally, we combined all the elicited factors, organized them into categories and put them into a list of SPI sustainability success factors. It is this list that constitutes

the body of this paper and a foundation for the creation of the SPI health attributes in [48].

B. Questionnaire

When educing knowledge about the SPI success factors, we used open-ended and semi-structured interviews [47]. This helped us encourage our interviewees to provide additional information that might be found useful for understanding the factors.

The interview structure was based on the questionnaire presented in Table I. Its questions were aimed at identifying both success and failure factors. Therefore, the questionnaire was structured into the following five groups of questions: (1) reasons for why SPI efforts have been lasting, (2) reasons for why SPI efforts have not been lasting, (3) factors contributing to the SPI sustainability, (4) factors preventing the SPI sustainability, and finally, (5) suggestions for how to keep the SPI efforts sustainable.

C. Validity

All the qualitative research methods encounter validity threats [47]. Those threats concern *construct validity, internal validity* and *external validity*.

Construct validity refers to the degree to which inference can be made from the operational definition of a variable to the theoretical constructs [49]. The main threat to *construct validity* is to guarantee that the right measures have been chosen for the study. Here, the risk was that we might use wrong measures, and as a result, we might misinterpret the SPI sustainability success factors. To minimize this threat, we conducted both theoretical and empirical studies. Moreover, we employed the multiple sources of data during the empirical study by interviewing different roles in twelve different organizations.

Internal validity refers to the degree of inferences of the cause-effect or causal relationships in the study [49]. The main threat to *internal validity* for the literature study was the fact that we might misinterpret the conclusions presented in the literature or use too few literature sources. Therefore, in this study, we first made a comprehensive search in various scientific sources out of which we extracted 27 experience reports. The main *internal validity* threat for the empirical study was that the interviewees might have misunderstood the impacts on the SPI sustainability. To minimize this threat, we used various roles involved in SPI in different software organizations.

External validity refers to the degree of whether the sample findings can be generalized [49]. The main *external validity* threat to our empirical study was the fact that the SPI sustainability factors that had been identified during the interviews were based on the experiences of only 45 individuals who belonged to medium-sized software companies. Therefore, we believe that the empirical findings of this study should be found more useful for medium-sized software companies. Nevertheless, by incorporating them with the results of the literature study, we are confident that our findings and conclusions are useful for all sizes of software companies whether large, medium-sized or small.

IV. SPI Sustainability Success Factors

In this section, we present the identified factors that lead to the success and sustainability of the SPI efforts. Some of them have direct influence over the SPI success and sustainability whereas some other factors have an indirect influence. Therefore, when describing them, we state their influence wherever it is relevant.

Based on both literature and empirical studies, we have identified thirty three SPI sustainability success factors. During the literature study, we have identified twenty seven SPI success factors, out of which twenty four factors overlapped with the factors that have been identified during the empirical study. The interviews have additionally resulted in six new SPI factors.

Just because these two studies were done independently, they had led to two groups of SPI success factors: (1) the ones that are common to the two studies, and (2) the ones that have been elicited within one type of a study but not within the other. When describing them in this section, we clearly identify their sources. Additionally, we list them and their sources in Tables II, III and IV.

To facilitate our presentation, we group the elicited SPI sustainability success factors into three categories as defined in [18]. These are *organizational factors, implementation factors* and *social factors*. The factors are described in Sections IV.B, IV.C and IV.D that follow Section IV.A, which briefly presents the core SPI roles that may vary in different academic and industrial contexts.

A. Roles

Many different roles are involved in process improvement. Their naming and responsibilities vary in different academic and industrial contexts. For this reason, we identify and define the following roles involved in SPI:

- *Stakeholder*: a person or a group that is involved in or affected by SPI. Stakeholders include all the internal and external roles that are influenced by SPI.
- *Technical staff:* a group consisting of developers, testers, development managers, support personnel and other roles involved in executing the process undergoing the improvement. They are the "doers" within the process undergoing improvement, and therefore, they get affected by the process change the most.
- *External SPI leader:* a person or a group that is in charge of the overall SPI process. He/she initiates the improvement projects, requests resources, encourages local improvement efforts and establishes communication channels between different groups. External SPI leader is not the doer in the process to be improved. For this reason, he/she is seen as an external and independent role.
- *Internal SPI leader:* a person or a group within the technical staff who is responsible for supporting and following the SPI strategy on a local process level.

B. Organizational Factors

Organizational factors are critical success factors that are related to the organizational structure, politics and culture [18]. They have a substantial impact on the SPI effort and its sustainability.

Table II shows nine organizational factors. We have grouped them into three clusters: 1) *Support of SPI* focusing on the management support and sponsorship of the SPI project, 2) *Resources* targeting people resources required for conducting the SPI project, and 3) *Alignment*

aiming at aligning SPI with the organization-related factors. The organizational SPI success factors are following:

1) Management continuously supports and committs to the SPI process

To provide long-term sustainable results, software improvement requires continuous investment in time, resources and effort. This, in turn, requires that management is strongly committed to and continuously supports the SPI efforts [6], [7], [18], [20], [28]. Strong management commitment helps retain high priority of the SPI projects and the continuous management support helps assure continuous supply of the required resources. It is especially important in the initial SPI phases during which the cost of the SPI activities is higher than the initially expected and planned cost [4].

Even our interviewees have stated that SPI projects need investment in time and resources in order to achieve sustainable results. According to them, this cannot be achieved without commitment and support of top management. Without management support, the SPI effort and results are doomed to decay. Our interviewees have also pointed out that management should prioritize the SPI activities and assign resources to them. This will prevent the SPI activities from getting neglected.

2) Resources are dedicated to SPI

Resources that are fully or partly dedicated to the SPI activities are the most important organizational SPI success factor. As many as 72% of SPI improvement projects have suffered from lack of resources and constant time pressure [4], [8], [19], [26].

According to the literature studied, SPI projects need to have dedicated time and resources. SPI projects cannot run on their own. Investment in resources has been recognized not only for starting and implementing the SPI projects but also for sustaining the achieved results [4], [5], [8], [9], [11], [18], [21], [26].

Our interviewees were of the same opinion. According to them, without dedicated resources, SPI can only rely on the engagement of individuals. The engagement however tends to decrease with time. Therefore, to guarantee the sustainability of the SPI efforts, it is important to dedicate resources to both the SPI and to the process undergoing the SPI.

3) SPI responsibilities are clearly specified and compensated

Clarity in the definition of the SPI roles and their responsibility assignments are very important. According to the literature studied, people involved in SPI should have clear responsibilities and compensation for their effort [4], [5]. If they are assigned to the SPI related tasks, they should be relieved from other tasks. Time dedicated to the SPI activities should be compensated in the same manner as other work. Otherwise, the SPI activities may be done in a rush, they may be neglected, they may be delayed or they may even be forgotten.

Our interviewees were of the same opinion. According to them, process related problems often start when no one is responsible for the process.

4) Competent external SPI leaders are designated

According to the literature studied, the level of competency, experience, commitment and engagement of the external SPI leaders can greatly determine the success of the SPI projects [4-6], [18]. However, as [4], [5] claim, this may not always be enough. Authority and respect paid to the external SPI leaders is just as important. Even if the SPI leaders are in a privileged position, it still does not imply that they have high enough authority, trust and respect among the technical staff members. If so, then their ideas may not be supported and successfully transmitted to the process change [4-6], [18]. Trust and respect may only be gained via personal qualities such as honesty, credibility, reliability, experience, reputation and good leadership.

TABLE II. ORGANIZATIONAL FACTORS

Cluster	SPI sustainability success factor	Recognized in literature	Recognized by No. of interviewers
Support of SPI	1. Management continuously supports and commits to the SPI process	[4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [16], [17], [18], [20], [21], [22], [23], [24], [25], [26], [27]	18
	2. Resources are dedicated to SPI	[3], [4], [5], [8], [9], [11], [16], [18], [19], [20], [21], [22], [23], [25], [26], [27]	18
Resources	3. SPI responsibilities are clearly specified and compensated	[4], [5], [10], [11], [16], [17], [19], [27]	14
	4. Competent external SPI leaders are designated	[4], [5], [6], [9], [10], [11], [12], [13], [16], [18], [20], [23], [27], [30]	22
	5. Internal SPI leaders are designated	[3], [6], [7], [10], [12], [13], [18], [20], [21], [23], [24], [27]	6
	6. The level of technical staff turnover is low	-	4
Alignment	7. SPI is aligned with business goals	[12], [13], [16], [18], [21], [22]	-
	8. SPI is aligned with organizational policies and strategies	[4], [16], [17], [19], [21], [26]	-
	9. SPI methods are tailored to specific organizational contexts and needs	[3], [6], [17], [18], [22]	11

The importance of the external SPI leaders was also raised during the interviews. According to our interviewees, to make the SPI results last, there should be an external SPI leader, a person or a group of people who have knowledge of SPI and who take on the responsibility of driving it. The external SPI leader should lead the people and guide the process towards a continuous and sustainable improvement.

5) Internal SPI leaders are designated

Since external SPI leaders and managers are not directly involved in the development process, it is important to have internal leaders as well. According to the literature studied, the internal SPI leaders are recognized as *important SPI actors* since they take on the immediate responsibility for leading and supporting continuous process improvement [6], [7], [20], [21]. By possessing knowledge of the process, they are able to adapt the improvement suggestions to the different needs of the development teams, projects and cultures. They help SPI activities get started and their engagement aids in winning support of their team members towards SPI [20].

The importance of designating internal SPI leaders was also recognized during the interviews. According to our interviewees, the involvement of the internal SPI leaders helps spread commitment to the process and create strong process ownership. Internal leadership creates continuous control that the development process is followed in a correct way and that the technical staff is engaged in SPI.

6) The level of technical staff turnover is low

According to our interviewees, high people turnover can become a significant barrier to the sustainability of the SPI efforts. When the key employees leave the company, so does the knowledge of the process and SPI. With a high technical staff turnover, more effort needs to be spent on the education and training of the new hires.

7) SPI is aligned with business goals

The goals of SPI projects should not only go in line with the standardization of the process and quality standards, but also with the business goals of the company. According to the literature studied, alignment of SPI goals with the organizational business goals contributes to the better management of, commitment to and support of the SPI projects [12], [13], [18], [21], [22].

8) SPI is aligned with organizational policies and strategies

Improvement projects often conflict with the existing organizational policies by requiring changes to the routines and processes that are common to the whole organization. Therefore, as stated in the literature studied, organizational policies have to be aligned with the SPI goals and vice versa.

In cases when organizations do not have any policies, they have to establish ones and make the process standardization and improvement coherent with them. Lack of organizational policies to support process changes can potentially become a big barrier for a successful process improvement [4], [19], [21], [26].

9) SPI methods are tailored to specific organizational contexts and needs

Each organization is different with respect to its structure, culture and policies. For this reason, as stated in the literature studied, SPI initiatives should consider the contextual specifics of the organizational culture, product characteristics, customer availability and people influenced by the process. The adaptation of process improvement methods to the specific organizational contexts and needs helps address individual problems and contributes to sustainable SPI efforts [6], [18].

The interviews have led to the same conclusion. According to our interviewees, if the SPI is not aligned with the organizational needs, or if it does not fit the established organizational and national culture, then it is more difficult to win people's support and commitment. Moreover, the people will resist process changes and the results achieved by SPI will be easily lost.

C. Implementation Factors

We have elicited fourteen implementation factors. They are all related to the planning, preparation, execution and management of the SPI projects. As shown in Table III, they are grouped into four clusters: 1) *Education and knowledge* focusing on training and expertise of stakeholders, 2) *SPI strategy* targeting preparation and vision of the SPI project, 3) *SPI management and execution* dedicated to issues related to management and execution of the SPI project, and 4) *Continuity of SPI effort* focusing on the mechanisms for enabling the continuity of the SPI effort. The factors are the following:

1) Stakeholders are trained in software process

Process improvement often implies changes to the process in form of introduction, removal or modification of new techniques and practices. Hence, as pointed out in the literature studied, the technical staff needs to be trained in the process and its techniques and practices in order to fully understand their role in the process change. They need to be prepared for the process improvement and understand the reasons behind each suggested change. Moreover, other stakeholders that are affected by SPI should also receive necessary training. Otherwise, they will less likely follow the new process [19]. For this reason, it is needed to train the stakeholders in the new process, new techniques and practices not only for supporting the implementation of process changes but also for sustaining improvement results. In organizations or cultures where knowledge of the process is low, the training in the process is even more important [26]. The levels of training may differ from stakeholder to stakeholder with respect to the stakeholders' training needs and their level of involvement in SPI.

The need for adequate process training was also raised during the interviews. According to our interviewees, all the company employees need to have necessary training in the new method in order to understand it and to be able to follow it properly and dedicatedly. The process training increases employee motivation in the SPI and decreases resistance to process change.

2) Stakeholders are continuously mentored and coached

Training in the new process contributes to its understanding and allows stakeholders to follow it dedicatedly. Still however, according to the literature studied, training in the software process may not be enough. Some stakeholders may misunderstand the process or continue following old techniques and practices. Therefore, the stakeholders should be mentored and coached in SPI and the process changes. [7], [23].

TABLE III. IMPLEMENTATION FACTORS

Cluster	SPI sustainability success factor	Recognized in literature	Recognized by No. of interviewers
Education and knowledge	1. Stakeholders are trained in software process	[3], [4], [7], [8], [9], [11], [18], [19], [20], [21], [22], [23], [24], [25], [30]	31
	2. Stakeholders are continuously mentored and coached	[3], [7], [8], [9], [23], [25]	19
	3. SPI leaders possess experience and expertise in SPI	[7], [8], [9], [16], [18], [19], [21], [22], [25], [26], [27], [30]	17
SPI strategy	4. SPI goals and objectives are clear and realistic	[4], [5], [6], [12], [13], [16], [17], [18], [19], [21], [22]	15
	5. SPI method is well defined	[7], [8], [9], [16], [17], [18], [20], [24], [25], [26]	-
SPI management and execution	6. SPI project is effectively managed	[6], [8], [9], [16], [19], [25], [26], [30],	16
	7. Process improvements are focused on specific areas	[20], [21], [22], [27]	2
	8. Process improvement effort is flexible	-	11
	9. Information about SPI activities and its results is disseminated	[6], [9], [10], [12], [13], [17], [19], [22], [26]	26
	10. Process standards are defined and enforced	-	17
	11. SPI effort brings positive results	-	18
Continuity of SPI effort	12. Software process is monitored and measured	[3], [6], [7], [12], [13], [17], [20], [21], [23], [27]	21
	13. Software process and its efficiency are continuously reviewed	[2], [3], [7], [8], [10], [12], [13], [22], [23], [24], [25], [27]	13
	14. SPI effort is continuous	[2], [8], [11], [14], [27]	23

According to our interviewees, the internal SPI leaders and other stakeholders responsible for the improvement activities have to be coached by the experienced external SPI leaders on how to implement improvements and how to follow the new process. Continuous mentoring and coaching increases the credibility of the strategic SPI decisions and contributes to building trust both in those decisions and in the new process.

3) SPI leaders possess experience and expertise in SPI

Process improvement implies changes to the deeply ingrained organizational culture, habits, working patterns and manners that have been developed throughout a long time. To change them is very difficult. According to the literature studied, however, it is easier to change them if the SPI team possesses enough knowledge and experience in implementing software process improvement changes. If there is lack of such knowledge and experience, then there is a risk of using unsuitable SPI strategy and of having poor SPI execution, which could potentially fail the SPI projects [7-9], [19], [25], [29].

Our interviews have also led to the same conclusion. The interviewees have mentioned the importance of the experience and expertise to be possessed by the SPI leaders.

4) SPI goals and objectives are clear and realistic

SPI projects should have clearly specified goals and objectives. Our literature study shows that clear, realistic and well communicated SPI goals contribute to good understanding of the SPI process and assurance that they are well understood across all the organizational levels [5].

Realistic SPI goals lead to realistic expectations and aid in maintaining high motivation for and support of the SPI activities. Unrealistic, too ambitious or unreachable objectives, on the other hand, may jeopardize the SPI projects, by decreasing employees' engagement and motivation even in projects with positive results [4], [21]. Our interviews have led to a similar conclusion.

5) SPI method is well defined

Software process improvement is a complex and time consuming process. Following a well defined and structured SPI implementation method strongly contributes to its success [7], [9], [25]. According to the literature studied, the SPI method should be suitable to the organization, its size and goals.

6) SPI project is effectively managed

Management of the SPI project involves a wide range of activities such as planning for change, identifying actors involved, ensuring the level of understanding the process changes, monitoring the status of SPI, evaluating the progress, and the like. It needs to be performed in an effective and professional manner [26]. According to the literature studied, without project management, the SPI project is doomed to fail or it may lead to chaos [6].

Our interviews have pointed out that effective management and execution of SPI are key elements of the successful SPI effort and its sustainable results.

7) Process improvements are focused on specific areas

At the beginning of the SPI projects, companies can be overwhelmed with the amount of suggestions for the improvements. Such being a case, as stated in the literature

studied, it is important not to do too many changes at once. Instead, companies should focus on a few specific process areas and a few process improvement goals. They should also prioritize the SPI suggestions and implement only one or few improvements at a time [20], [21]. This leads to easier and more efficient implementation, control, measurement, and thereby, to more sustainable results of SPI efforts.

Our interviews have led to the same conclusion. The interviewees added that process changes should be introduced in a slow manner and supported by training sessions. This can contribute to the understanding of the process undergoing change and of the impact of the process changes.

8) Process improvement effort is flexible

Software process should continuously change and adapt to the organizational needs and situation. SPI activities can be risky and may not always lead to the expected results. Therefore, according to our interviewees, process improvements should be flexible and allow for experimenting with the process. In cases when the process change is proven to be unsuccessful or unsuitable, the organization should be able to quickly rollback the process to the pre-change status.

9) Information about SPI activities and its results is disseminated

SPI projects bring many changes to the process and daily routines. These changes have to be communicated to all the stakeholders that can be directly or indirectly impacted by the changes. According to the literature studied, insufficient communication of the SPI changes may lead to lack of transparency of the SPI projects, confused personnel and poor quality process. Team collaboration and communication, on the other hand, may help the staff members to exchange knowledge and experience during the improvement projects and contribute to a more coherent organizational culture [6].

The need for communicating on the SPI activities and their results has also been raised by our interviewees. According to them, sufficient communication positively impacts motivation in SPI and acceptance of the new process changes.

10) Process standards are defined and enforced

In some companies, the newly introduced process can just run by itself. Its main fuel is primarily high commitment and engagement of the technical staff. However, in companies that have low commitment towards or poor understanding of the development process, people are tempted to disregard the process standards, unless there is a strong control mechanism in place [34]. Even when properly trained, the staff may not follow the newly introduced process. Therefore, as stated in the literature studied, in order to guarantee that the process is dedicatedly followed by all the stakeholders, it should be enforced and controlled by the SPI managers [34].

Our interviews have led to a similar conclusion. The interviewees have also suggested that the employees that are not following the software process procedures correctly should be informed and consequently corrected. The interviewees also highlighted the importance of accessible and updated software process documentation.

11) SPI effort brings positive results

As mentioned before, the results of the SPI activities should be disseminated to all the stakeholders. However, as discovered during the interviews, just the dissemination of the SPI results is not enough. The results achieved by the early SPI effort should be positive and should speak for themselves.

Early gains of SPI effort can encourage and motivate stakeholders to continue with the SPI activities and can change the opinions of those who did not support SPI from the very beginning.

12) Software process is monitored and measured

Continuous process monitoring and measurement indicates whether the SPI activities are effective or not, and allows to provide early feedback on the sustainability of the SPI efforts. Hence, as stated in the literature studied, it is important to evaluate and measure the process on a continuous basis in order to reinsure its purpose and to increase the engagement of the SPI supporters. Measured and acknowledged process improvement will positively affect team morale and motivation [7], [12], [13], [20].

Our interviewees have also stated that measurement and evaluation of the SPI results can positively impact the engagement in and motivation for future SPI.

13) Software process and its efficiency are continuously reviewed

To achieve continuous process improvement, the SPI process and its efficiency should be reflected on and evaluated on a continuous basis. As stated in the literature studied, process reviews, such as retrospectives, allow learning from previous experience and from experimenting with the process, which, in turn, contributes to a self-driven continuous process improvement, and thereby, to long lasting SPI results [12], [13].

Our interviews have led to the same conclusion. According to our interviewees, process reviews help to identify problems in the current process and to acknowledge benefits achieved by SPI. This, in turn, significantly contributes to the sustainability of the achieved results. Without frequent reviews and changes to the process, gains of SPI will soon outdate.

14) SPI effort is continuous

Software organizations have dynamic and continuously changing structures. Organizational culture, availability of the customer and background of the employees are always changing. Hence, a static process that is not improving or adapting to the changing organizational needs is failed to decay [34]. Moreover, the results of the SPI efforts will be lost if the organization will stop improving its process.

To sustain the gains of the process improvement efforts, the company should view the SPI as a continuous activity. According to the literature studied, continuous SPI effort cannot be achieved without mechanisms for continuous process review and tuning [34], and comprehensive support of those responsible for the process [6]. In addition, all the roles responsible for the SPI project should continuously reaffirm commitment to change, communicate progress of improvement, and provide continuous feedback and motivation [6].

Our interviews have also confirmed that time and money should be continuously invested into the SPI effort in order to maintain its results.

D. Social Factors

We have identified ten different social SPI sustainability success factors. Social factors deal with human behavior and reactions in the SPI context. As shown in Table IV, they are grouped into three clusters: 1) *Understanding and awareness of SPI* focusing on common understanding and awareness of the SPI, 2) *Attitude to SPI* targeting stakeholders' attitude towards SPI, and 3) *Facilitation of SPI* listing factors that may increase stakeholders' motivation in SPI. The social SPI success factors are the following:

1) Stakeholders have a common understanding of the process undergoing change

The process cannot be efficiently improved unless it is properly understood. According to the literature studied, the technical staff and management have to reach consensus on the status of the current process, its problems and possible solutions, as well as the organization's vision and improvement goals [6]. Common understanding of the current and new process, suggested changes and its potential benefits are important to increase support for process improvement among all the stakeholders involved.

Our empirical study has led to the same conclusion. According to our interviewees, all the stakeholders should understand the reasons behind process changes. An important stakeholder here is the technical staff who has to change the previous habits and adapt to a new way of working. Our interviewees have also pointed out that common understanding of the new process, of the SPI activities and their potential benefits strongly contribute to the increase of commitment and motivation towards SPI.

2) Stakeholders are aware of complexity, challenges and benefits of SPI

Since SPI requires continuous effort and often brings mainly long-term results, it is important that everybody involved in it is aware of its complexity, challenges and future benefits. Hence, according to the literature studied, organizations must make sure that all the stakeholders involved are aware of complexity and potential benefits of SPI. This can be realized via education, training and effective communication. Raising awareness of SPI and effective communication of its complexity, challenges and benefits strongly affects the success of the SPI projects [8-10], [23-26].

Our interviews have also shown that the stakeholders need to understand the reasons behind SPI and its potential benefits in order to accept and commit to the process change.

3) Stakeholders have realistic expectations

Our interviews have indicated that in order to be satisfied with SPI and its results, the employees affected by SPI should have realistic expectations. Otherwise, the stakeholders will get disappointed with SPI and will not continue with it, even though SPI brings positive results.

4) Technical staff accepts SPI activities

Changes to the process may affect daily work of many employees. Therefore, according to the literature studied, it is important that all the members of the technical staff agree and accept future process changes [18], [27]. This can substantially decrease inertia to change. Acceptance of process changes can be encouraged by high involvement of the technical staff in the SPI activities.

Our interviews have also led to the same success factor. According to our interviewees, if all the personnel accept the newly changed process, then there is a greater opportunity that the changed process will be sustained. Mutual acceptance of the changed process and SPI activities is a key to sustain the results achieved by the SPI.

5) Technical staff is committed to the SPI process

Acceptance of SPI activities is a critical success factor when starting SPI projects. According to the literature studied, however, it needs to be complemented with the

TABLE IV. SOCIAL FACTORS

Cluster	SPI sustainability success factor	Recognized in literature	Recognized by No. of interviewers
Understanding and awareness of SPI	1. Stakeholders have a common understanding of the process undergoing change	[6], [11]	17
	2. Stakeholders are aware of complexity, challenges and benefits of SPI	[8], [9], [10], [17], [20], [23], [24], [25], [26]	4
	3. Stakeholders have realistic expectations	-	4
Attitude to SPI	4. Technical staff accepts SPI activities	[3], [16], [18], [27]	24
	5. Technical staff is committed to the SPI process	[3], [16], [21], [22], [23], [24]	10
Facilitation of SPI	6. Stakeholders are being encouraged to support SPI	-	16
	7. Technical staff is rewarded for contribution to SPI success	[7], [9]	4
	8. SPI leaders encourage initiative and openness of stakeholders	[11], [12], [13], [19]	2
	9. Technical staff participates in SPI	[3], [4], [5], [6], [8], [9], [10], [12], [13], [18], [21], [23], [24], [25], [27], [30]	22
	10. Technical staff owns the software process	[3], [5], [7], [18], [27]	20

commitment of the technical staff. Commitment to the SPI projects is inevitably another significant success factor to sustain the results of the SPI projects.

Management commitment to SPI projects has already been listed as a significant SPI success factor. However, commitment of technical staff is just as important [21-24], [28]. Together with the increased motivation and engagement, the commitment of the technical staff can become a driving wheel of process improvement [3]. Committed staff takes on the responsibility and ownership of the process and keeps process in a healthy state [3].

Commitment of the technical staff has also been educed during our interviews. Our interviewees have stated that if the company personnel does not commit to the process changes, it will most likely go back to the pre-SPI process state.

6) Stakeholders are being encouraged to support SPI

Commitment to and support of SPI by all the stakeholders is a great asset to help successful SPI implementation and to decrease inertia towards change. However, it is not easy to reach everybody's support of SPI. Therefore, our interviewees suggested that during the early stages of the SPI project, the management should start encouraging the stakeholders towards supporting SPI. Encouraging the technical staff in SPI from the very beginning would increase support, motivation and engagement in future SPI activities.

7) Technical staff is rewarded for contribution to SPI success

Moral appreciation and financial rewarding acknowledge individual contributions to SPI. Recognized contribution engages and motivates people to continue with the SPI effort [7], [34]. The technical staff should also be rewarded for showing interest in and for contributing to the process improvement activities.

According to our interviews, the organization should celebrate each SPI success and reward personnel for their contributions. This will increase overall motivation and commitment to SPI.

8) SPI leaders encourage initiative and openness of stakeholders

To be able to suggest future process improvements, the weaknesses and problems of the current process need to be continuously identified. Some of those weaknesses and problems can relate to specific individuals and fulfillment of their responsibilities. Therefore, it is important to focus on identifying the process weaknesses and not on playing *blame games* [19], which can only lead to frustration and inertia towards process change [11], [19].

According to the literature studied, SPI leaders should focus on process weaknesses and problems and should encourage initiative, innovation, creativity and openness in stakeholders involved. Without it, employees cannot share valuable ideas, and thereby, contribute to process improvement [11]. Few of our interviewees were of the same opinion.

9) Technical staff participates in SPI

Technical staff constitutes an important process knowledge and experience asset [6]. By knowing all the nooks and crannies of the process, the staff may provide useful feedback on the suggested SPI changes [27]. For this reason, it is important that they are involved in identifying process pains and in suggesting solutions for them [6], [8], [9], [12], [13], [18], [25].

The literature findings show that the involvement and participation of the technical staff reduce resistance to change, and thereby, strongly impact the SPI success [6], [18], [21]. By being involved in the SPI activities, the technical staff members feel more motivated to adhere to the process changes, and therefore, they are more likely to accept them [6], [18]. If, on the other hand, they are not convinced, then the process improvement projects will have small chances to succeed. Technical staff involvement was found especially important in immature organizations [25].

Many of our interviewers have also mentioned that the involvement of the technical staff contributes to the alignment of SPI methods to the organizational needs. It also decreases inertia towards change and increases motivation, and thereby, it significantly affects the sustainability of the SPI efforts.

10) Technical staff owns the software process

Disregarding the reasons behind the SPI projects, the new process has to be accepted and followed by the team. According to the literature studied, it is important that not only external and internal SPI leaders but also all the technical staff members take on the ownership of the process to be improved. The members should take the responsibility for tailoring the process and for continuously improving it. It is only in this way they will feel more affiliated with the process and more responsible for future process improvement. This, in turn, will lead to a built-in, self-driven continuous process improvement process, which, in turn, will strongly contribute to the sustainability of the SPI results [7].

Our interviewees have also stated that the success of the SPI projects is strongly related to software process ownership. According to them, not only management and SPI leaders should own the process, but also all the technical staff members. They should be responsible for the software process and its changes.

V. FINAL REMARKS

In this paper, we have presented thirty three success factors influencing the sustainability of SPI efforts. The factors are grouped into three categories: *organizational factors, implementation factors* and *social factors.* They were elicited in two independently conducted studies, the literature study and empirical study. The early results of this study were previously published in [1].

More than 70% of the identified SPI sustainability factors (24 out of 33) were commonly identified both via literature and empirical studies, even though they were conducted independently. Out of twenty seven success factors identified in the literature, only four were not mentioned by our interviewees. This represents a general approval of the SPI success factors identified in the literature, since the interviewees were not influenced by the results of the literature study. The factors that were not confirmed by the interviewees concerned two organizational factors dealing with the alignment of SPI with business goals and organizational policies and strategies (see Section IV.B.7 *SPI is aligned with business goals*, and Section IV.B.8 *SPI is aligned with organizational policies and strategies*) and one

implementation factor dealing with the definition of the SPI method (see Section IV.C.5 *SPI method is well defined*). The reason to why those factors were not mentioned by our interviewees could be that they concerned management and business level of the SPI project that was more common to larger organizations and less applicable for medium-sized organizations to which all our interviewees belonged to.

During the interviews, we have identified thirty SPI success factors, from which only six were not previously reported in the literature. Those factors concerned one organizational factor dealing with technical staff turnover (see Section IV.B.6 *The level of technical staff turnover is low*), three implementation factors dealing with process improvement and process standards (see Sections IV.C.8 *Process improvement effort is flexible*, Section IV.C.10 *Process standards are defined and enforced*, and Section IV.C.11 *SPI effort brings positive results*, and finally, two social factors dealing with the stakeholders' expectations from and encouragement towards SPI (see Section IV.D.3 *Stakeholders have realistic expectations*, and Section IV.D.6 *Stakeholders are being encouraged to support SPI*. Those factors represent lessons learned from SPI adaptation in the interviewed companies. Therefore, they may be context dependent and not necessarily applicable to other software organizations. Nevertheless, they clearly contribute to the SPI success and sustainability as stated in Section IV.

Despite the high overlap of the identified factors, the focus on the factors differed greatly among the sources used in this study. The literature sources mainly focused on conditions enabling the SPI efforts. The SPI factors that were recognized by the majority of the literature sources dealt with continuous management commitment and support, provision of resources and involvement of the technical staff in SPI (see Section IV.B.1 *Management continuously supports and commits to SPI process*, Section IV.B.2 *Resources are dedicated to SPI*, and Section IV.D.9 *Technical staff participates in SPI*). Those factors have the most devastating impact on the SPI project. Without them, the SPI project should not even be initiated. Their importance and influence were also confirmed during the interviews.

The factors that were mentioned by most of the interviewees focused on the social factors and the effects of SPI on the daily routines. Their concern mainly dealt with down to earth issues such as training in software process undergoing improvement, availability of the information on the SPI activities and results, and acceptance of the SPI activities by the technical staff (see Section IV.C.1 *Stakeholders are trained in software process,* Section IV.C.9 *Information about the SPI activities and its results is disseminated*, and Section IV.D.4 *Technical staff accepts SPI activities*). This may be explained with the fact that the majority of our interviewees have taken part in the SPI projects but they did not lead them. Therefore, our interviewees represented the developers' view from the perspective of how SPI affects their way of working and their daily routines.

The SPI sustainability success factors presented in this paper constitute the body of knowledge of the software engineering community as educed in the current software engineering literature and in the industry. Even if they have only been listed and described, they may already constitute a basis for providing insight into SPI efforts, for diagnosing the reasons of SPI decay or for confirming the prerequisites that are necessary for carrying out SPI.

We strongly believe that it is not enough to just define SPI process frameworks and/or models. The process frameworks/models should be supported by tools for evaluating the status of the SPI projects and identifying its faults. For this reason, we plan to continue working with the SPI sustainability success factors presented in this paper. Our goal is to create a basis for supplementing currently defined SPI frameworks and/or models with a checklist for SPI effort evaluation.

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